Kellerman, W. A. & Swingle, W. T.

EXPERIMENT STATION,

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AGRICULTURAL COLLEGE,

MANHATTAN, KANSAS.

BULLETIN NO. 15.—DECEMBER, 1890.

BOTANICAL DEPARTMENT.

ADDITIONAL EXPERIMENTS AND OBSERVATIONS ON OAT SMUT, MADE IN 1890.

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ADDITIONAL EXPERIMENTS AND OBSERVATIONS ON OAT SMUT, MADE IN 1890.

HAVING published in Bulletin No. 8, ("Preliminary Report on Smut in Oats,") and in the Second Annual Report of this Station, ("Report on the Loose Smuts of Cereals,") full accounts of the structure and life history of the oat smut fungus, *Ustilago Avenæ* (Pers.) Jensen, accompanied with figures, it is unnecessary to restate more, by way of introduction, than that the black powdery mass of smut is made up of innumerable tiny bodies called *spores*. These are reproductive bodies of the parasite, and therefore correspond in function to seeds of common plants. The spores blown about by the wind while the oats are in bloom and while the young grains are being formed, find lodgement inside the husks. When the seed is planted in spring, the smut spores germinate by sending out a delicate thread-like tube which at once penetrates the oat-seedling through its tender first leaf-sheath. The parasite is thereafter wholly concealed by its host. It develops simultaneously with the latter and enters the young grain in the early stage of its formation. Here a thick mass of threads is formed and in these the spores are produced. This mass of spores, as mentioned above, is the so-called smut.

OUTLINE OF BULLETIN.

In this Bulletin, which is mainly a continuation of work previously reported upon, will be given observations as to the amount of smut and an account of experiments in preventing oat smut in 1890; also a brief state-

ment as to hidden smut, accompanied with a plate of illustrations, and a discussion of the remarkable increase in yield as a result of the use of the Jensen hot-water treatment; finally, full directions for treating seed to prevent the smut.

AMOUNT OF SMUT.

In order to determine the amount of smut present in fields near Manhattan, fifteen counts were made, in the following manner. A light frame, enclosing exactly four square feet, was set down at random in the field. All the heads included in the frame were then counted, and the number of smutted ones determined. Finally the hills containing smutted heads were pulled up and examined to see whether all the heads were smutted or whether part of them were sound. Several of such areas were counted in each field and the results combined.

Besides these fifteen counts made at Manhattan, Mr. Burt Tidball and Mr. John J. Doyle each made one count in the vicinity of Oswego, Labette County, Kansas; and Mr. A. M. Nissen made three counts near Wetmore, Nemaha County, Kansas.

All of the above counts are given in the following table, the first fifteen being made at Manhattan:

TABLE SHOWING AMOUNT OF OAT SMUT IN KANSAS, 1890.

Count.	Name of variety.	Character of soil.	Hei't of pl'nts in inches.	Total heads counted.	Smutted heads	Per cent. smutted.	Total hills containing smutted heads	Hills entirely smutted.	Hills partially smutted.	S'nd heads in partially smutted hills.	Smutted heads in partially smutted hills.
1	White Winter.	Rich upland, sloping...	22	2114	180	8.51	151	147	4	4	8
2	.....	Rich cr'k bottom, level.	25	2049	92	4.49	59	57	2	2	2
3	.....	Very rich creek bottom (in old pig pen)	23	1160	48	4.13	32	32	0	0	0
4	.....	Rich creek bottom, sloping,	23	1337	59	4.41	48	48	0	0	0
5	Black Winter.	Upland.....	22	1764	30	1.70	27	27	0	0	0
6	.....	Upland.....	24	1247	57	4.51	40	38	2	5	4
7	.....	Immediately adjoining count 6,	20	1111	111	9.99	70	70	0	0	0
8	White Winter.	Poor clay upland.....	22	1621	50	3.08	40	39	1	1	1
9	White and bl'k mixed,	Rich level creek bottom	19	2094	127	6.06	15	15	0	0	0
10	Winter.....	Rich upland, sloping..	19	643	78	12.13	26	23	3	6	5
11	White Winter.	Adjoining count 8 (seed same?),	20	1380	55	3.98	39	37	2	5	4
12	Bonanza.....	Rich level creek bottom	25	2276	613	26.93	639	628	11	34	41
13	White Winter.	Adjoining count 12.....	22	2151	54	2.51	55	50	5	7	6
14	Red Winter...	College, Bull. 13, p. 63, plots 93-107,	20	1691	180	10.64	162	161	1	4	1
15	Badger Queen.	College, upland ravine.	26	1909	207	10.84	171	168	3	5	5

TABLE SHOWING AMOUNT OF OAT SMUT IN KANSAS, 1890.—CONCLUDED.

16*	Red Texas	Rich second bottom, sloping,	25	388	4	1.03	2	1	1	3	1
17†	Red or Texas		30?	500	21	4.20					
18‡		Second bottom and upland,	23	2298	44	1.91					
19‡		Level upland	18	2160	33	1.53					
20‡		Poor upland	20	1551	104	6.62					
		Average pr. ct. of smut				6.46					

* Counted in Labette County, Kansas, near Oswego, by Burt Tidball.
† Counted in Labette County, Kansas, near Oswego, by John J. Doyle.
‡ Counted in Nemaha County, Kansas, near Wetmore, by A. M. Nissen.

The average per cent. of smut in the twenty counts is only 6.46, an amount considerably smaller than that obtained for 1888 and 1889. However the fields about Manhattan averaged (in 1890) 7.59 per cent. smutted.

Two other reports were received in regard to the amount of smut in Kansas the present year. Mr. Thos. Bassler, at Geuda Springs, Sumner County, says: "Very little smut in this locality; would have to go over a large field to get a dozen heads." On the other hand Mr. W. W. Robison, at Yates Centre, Woodson County, reports that "the smut is very bad in this locality; in some fields nearly half the heads are smutted."

Besides the above counts made in fields, others were made in the plots of the single-plant variety tests of the Farm Department. These counts were made under peculiarly favorable circumstances, and therefore deserve especial mention. Eighty varieties were planted (without treatment with a fungicide) in a series of small plots where the plants were grown singly at a distance of eight inches apart. The plots should have contained 200 plants, but some of them had less. Grown in this manner, the plants had every opportunity to stool without confusion of the hills. This is given in Bulletin No. 13 of this Station (p. 54), by the Farm Department, as the VII Series of experiments, "Oats Grown as Single Plants," with a foot-note appended as follows:

"Not reported. Two hundred single plants of each of 80 varieties were planted, each plant having a space of 64 square inches. The objects were, to study their growth, and to note the quality of the grain compared with the grain of the same varieties grown under ordinary conditions; but the dry weather so affected the plants as to make a comparison unfair, and render the experiment all but worthless."

While the experiment was worthless for the purpose for which it was planned, it was nevertheless valuable for determining the amount of smut infesting the varieties. The plants or hills being so widely separated rendered the case especially favorable for studying the relative number of sound and smutted heads in the same hill. All the heads produced were counted in every plot, and all the counts were made by the same person. The following table shows the result:

TABLE SHOWING SMUT IN SINGLE-PLOT VARIETY TESTS, 1890.

Plot.	Name of variety.	Height of plants, in inches.	Total heads.	Smutted heads.	Per cent. smutted.	Total hills containing smutted heads.	Hills entirely smutted.	Hills partially smutted.	Sound heads in partially smutted hills.	Smutted heads in partially smutted hills.
1	American Banner	16	565	47	8.50	16	8	8	22	12
2	American Beauty	18	564	0	0	0	0	0	0	0
3	Badger Queen	24	521	19	3.64	6	4	2	5	4
4	Baltic	20	415	38	9.63	15	9	6	8	14
5	Belgian	24	471	0	0	0	0	0	0	0
6	Black American	24	900	0	0	0	0	0	0	0
7	Black Prolific	18	403	86	21.34	35	27	8	13	15
8	Black Russian	18	805	11	1.36	2	0	2	3	11
9	Black Swiss	12	129	0	0	0	0	0	0	0
10	Blue Grazing Winter,	.....	79	7	8.86	1	1	0	0	0
11	Board of Trade	24	512	1	.19	1	0	1	2	1
12	Brown Winter	24	851	30	3.52	9	5	4	9	15
14	Canadian Triumph	26	465	88	18.92	41	31	10	19	12
15	Centennial White	26	544	5	.91	3	1	2	2	4
16	Cream Egyptian	24	508	7	1.37	4	1	3	8	4
17	Colonel	18	537	24	4.47	8	5	3	5	8
18	Dakota Northern	26	512	260	50.78	94	84	10	22	15
19	Early Angus	14	58	7	12.07	1	1	0	0	0
21	Early Lackawanna	28	606	15	2.74	2	0	2	2	15
22	Early Poland	28	514	5	.97	2	2	0	0	0
23	Early Scotch	20	431	5	1.16	1	1	0	0	0
24	Egyptian	20	455	11	2.41	4	4	0	0	0
25	Flying Scotchman	20	594	79	13.30	34	22	12	35	28
26	Giant French	20	314	0	0	0	0	0	0	0
27	Gold Coin	20	381	3	.78	1	1	0	0	0
28	Golden Giant	18	296	4	1.35	1	1	0	0	0
29	Golden Sheaf	.....	660	0	0	0	0	0	0	0
30	Hargett's Seizure	28	555	21	3.96	10	4	6	14	7
31	Improved American,	20	566	28	4.94	8	7	1	2	1
32	Japan	21	512	3	.58	1	0	1	1	3
33	Kansas Hybrid	20	621	20	3.22	9	3	6	14	10
34	Monarch	20	972	30	3.19	6	5	1	3	4
35	New Brunswick	28	774	55	7.11	20	13	7	18	14
36	New Dakota Gray	20	445	1	.02	1	1	0	0	0
37	New Seneca Chief	23	466	153	32 83	57	48	9	18	18
38	New Swedish	22	517	77	14.89	30	25	5	7	13
39	North Western White,	22	828	13	1.57	3	2	1	1	5

TABLE SHOWING SMUT IN SINGLE-PLOT VARIETY TESTS, 1890 — CONCLUDED.

Plot.....	*Name of variety.*	*Height of plants, in inches.*	*Total heads.*	*Smutted heads.*	*Per cent. smutted.*	*Total hills containing smutted heads.*	*Hills entirely smutted.*	*Hills partially smutted.*	*Sound heads in partially smutted hills.*	*Smutted heads in partially smutted hills.*
40	Onega	22	635	30	4.72	10	3	7	17	14
41	Pedigree Red Rust Proof,	18	1055	12	1.13	3	0	3	10	12
42	Prince Edward's Island Black,	20	467	0	0	0	0	0	0	0
43	Pringle's Progress	26	681	166	24.38	43	35	8	24	16
44	Prize Chester	22	631	46	7.28	21	13	8	17	17
45	Prolific Side	26	661	0	0	0	0	0	0	0
46	Race Horse	21	610	12	1.96	4	2	2	5	4
47	Red Georgia	18	1204	0	0	0	0	0	0	0
48	Red Rust Proof	20	1115	46	4.12	15	6	9	39	30
49	Red Winter	22	1102	128	11.61	33	8	25	99	95
50	Rennie's Prize White,	28	663	257	38.76	92	56	36	70	88
51	Royal Victoria	30	599	16	2.74	7	5	2	4	4
52	Russian White	24	649	165	25.42	50	32	18	52	50
53	Scottish Chief	28	666	34	5.11	13	6	7	26	12
54	South Carolina Black,	20	860	0	0	0	0	0	0	0
55	State of North Dakota,	28	1091	28	2.56	7	4	3	6	10
56	Surprise		747	40	5.35	11	5	6	14	13
58	Victoria Prize White,	30	599	44	7.34	18	9	9	23	22
59	Virginia White	20	778	0	0	0	0	0	0	0
60	Waterloo	28	837	67	8.12	14	7	7	46	33
61	Welch	26	728	95	13.05	28	16	12	18	32
62	Welcome	30	715	83	11.60	32	19	13	35	33
63	White Australian	31	653	8	1.22	3	0	3	7	8
64	White Barley	30	800	6	.75	13	12	1	1	3
65	White Bedford		760	86	11.32	27	14	13	30	36
66	White California	28	960	10	1.04	2	2	0	0	0
67	White Canada	26	984	231	23.48	59	34	25	84	73
68	White Shower	28	881	72	8.17	22	7	15	47	39
70	White Swede	28	785	149	18.98	45	24	21	62	57
71	White Victoria	28	641	13	2.02	5	3	2	3	4
72	White Wonder	30	774	57	7.36	17	11	6	11	14
73	Wide Awake	30	604	212	35.10	67	47	20	28	53
74	Winter	16	437	0	0	0	0	0	0	0
76	Black Tartarian	28	541	0	0	0	0	0	0	0
77	Henderson's Clydesdale,	30	715	0	0	0	0	0	0	0
78	Hopetoun	20	572	8	1.39	3	2	1	1	4
79	Pringle's American Triumph,	30	579	22	3.79	11	6	5	6	13

It will be seen by inspecting the table that the amount of smut in the different plots is quite variable. Eight of the plots had more than a fifth of the heads smutted and one of these (18) was over half smutted; nine other plots were over 10 per cent. smutted; therefore 17, or nearly one-fourth of the 75 plots counted, were badly smutted. The source of the seed for each variety can be learned by referring to Bulletin 13.

The following varieties, having over 11 per cent. of smut, are arranged for convenience in the order of the amount of smut found in each:

Name of variety.	*Plot.*	*Per cent. smut.*	*Source of seed.*
White Bedford	65	11.32	R. and J. Farquhar & Co.
Welcome	62	11.60	David Landreth & Sons.
Red Winter	49	11.61	Kansas Experiment Station.
Early Angus	19	12.07	Colorado Experiment Station.
Welch	61	13.05	Ohio Experiment Station.
Flying Scotchman	25	13.30	Ontario Experiment Farm.
New Swedish	38	14.89	Price & Reed.
Canadian Triumph	14	18.92	Wm. Rennie.
White Swede	70	18.98	W. W. Barnard & Co.
Black Prolific	7	21.34	John A. Salzer.
White Canada	67	23.48	J. M. Thoburn & Co.
Pringle's Progress	43	24.38	Wm. Henry Maule.
Russian White	52	25.42	David Landreth & Sons.
New Seneca Chief	37	32.83	Morehouse & Cobb.
Wide Awake	73	35.10	David Landreth & Sons.
Rennie's Prize White	50	38.76	Wm. Rennie.
Dakota Northern	18	50.78	W. W. Barnard & Co.

Since the loss is often great in consequence of the use of smutted seed —*even 20 to 50 per cent.!*—farmers should not purchase of any seedsmen who could not guarantee cleanliness of the seed. The expense attending the employment of the hot-water treatment is so trifling that failure to disinfect high-priced seed is inexcusable in any dealer.

PARTIALLY SMUTTED HILLS.

In the above-described tests, the heads in the separate hills containing smut could be easily and accurately counted. Of the 1,101 hills containing smutted heads, 704 contained only smutted heads and 397, or 36 per cent., had both sound and smutted heads. In the table nothing more could conveniently be given than the number of sound and smutted heads produced in these partially smutted hills. Hence we may add the following: The 397 partially smutted hills produced 1,019 smutted heads,

or an average of 2.6 heads per plant, and 1,009 sound heads, or an aver- of 2.5 heads per plant. Each hill therefore had on the average 5.1 heads about half smutted and half sound. The 704 wholly smutted hills produced 2,265 heads, or an average of 3.2 per plant.

It is interesting to note that in the counts made in fields about Manhattan, where especial care was taken to ascertain the exact composition of the hills containing smut, nothing like so high a per cent. of the hills were partially smutted. In counts 1-16, of 1,576 hills containing smutted heads, 1541 were entirely smutted and only 35, or 2.2 per cent., were partially smutted. These 35 partially smutted hills produced 154 heads, or an average of 4.4 per plant; of these 78, or an average of 2.23, were smutted, and 76, or an average of 2.17, were sound. The 1,541 wholly smutted hills produced 1,862 heads, or an average of 1.2 to a plant. It will be noticed that while the proportions of wholly smutted and partially smutted hills is very different in the closely-planted fields and the very open single-plant tests, the partially smutted hills in both cases contain about one-half smutted and one-half sound heads on the average.

CHARACTER OF PARTIALLY SMUTTED HILLS IN SINGLE-PLANT VARIETY TESTS.

The following statement shows exactly the composition of the 397 partially smutted hills of the single-plant variety tests:

42	hills	had	3	smutted	and	1	sound	heads.	4	hills	had	6	smutted	and	1	sound	heads.
37	"	"	1	"	"	2	"	"	4	"	"	3	"	"	5	"	"
33	"	"	2	"	"	1	"	"	3	"	"	6	"	"	2	"	"
30	"	"	2	"	"	2	"	"	3	"	"	4	"	"	5	"	"
24	"	"	1	"	"	4	"	"	3	"	"	4	"	"	6	"	"
23	"	"	1	"	"	3	"	"	3	"	"	2	"	"	5	"	"
22	"	"	3	"	"	2	"	"	3	"	"	2	"	"	8	"	"
21	"	"	4	"	"	1	"	"	2	"	"	10	"	"	1	"	"
19	"	"	1	"	"	1	"	"	2	"	"	6	"	"	5	"	"
13	"	"	2	"	"	3	"	"	2	"	"	3	"	"	6	"	"
12	"	"	3	"	"	3	"	"	2	"	"	2	"	"	6	"	"
11	"	"	5	"	"	1	"	"	2	"	"	4	"	"	13	"	"
9	"	"	1	"	"	5	"	"	2	"	"	1	"	"	7	"	"
7	"	"	3	"	"	4	"	"	1	"	"	14	"	"	1	"	"
6	"	"	4	"	"	2	"	"	1	"	"	7	"	"	1	"	"
6	"	"	5	"	"	3	"	"	1	"	"	7	"	"	2	"	"
6	"	"	5	"	"	4	"	"	1	"	"	6	"	"	3	"	"
6	"	"	4	"	"	3	"	"	1	"	"	5	"	"	7	"	"
6	"	"	2	"	"	4	"	"	1	"	"	6	"	"	9	"	"
6	"	"	1	"	"	6	"	"	1	"	"	4	"	"	7	"	"
5	"	"	5	"	"	2	"	"	1	"	"	4	"	"	9	"	"
5	"	"	4	"	"	4	"	"	1	"	"	1	"	"	10	"	"

CHARACTER OF PARTIALLY SMUTTED HILLS IN COUNTS 1–16.

The following statement shows the character of the 35 partially smutted hills found in the counts made in ordinary fields of oats.

12 hills had 1 smutted and 1 sound heads.
5 " " 1 " " 2 " "
4 " " 2 " " 1 " "
2 " " 3 " " 1 " "
2 " " 6 " " 4 " "
2 " " 4 " " 3 " "
2 " " 3 " " 4 " "

2 hills had 2 smutted and 3 sound heads.
1 " " 4 " " 2 " "
1 " " 5 " " 4 " "
1 " " 3 " " 3 " "
1 " " 4 " " 5 " "
1 " " 2 " " 4 " "

SMUT FROM LIGHT, COMMON AND HEAVY SEED.

The Farm Department reported in Bulletin 13 (pp. 59 and 60), an experiment on the light, common and heavy oats for seed. We made counts in all of the plots (46–60) and the results are shown in the following table. Each line gives the average of counts made in the five plots planted with the kind of seed indicated. Five counts were made in different parts of each plot. In each count a space of four square feet was examined; hence the heads included in 100 square feet are given in each of the averages:

Character of seed.	*Height.*	*Total heads.*	*Smutted heads.*	*Per cent smutted.*	*Total hills containing smutted heads.*	*Hills entirely smutted.*	*Hills partially smutted.*	*Sound heads in part smutted hills.*	*Smutted heads in part smutted hills.*
Light	18	2969	274	9.23	277	275	2	2	4
Common	19	2838	376	13.25	318	314	4	8	11
Heavy	19	2829	305	10.78	227	223	4	10	12

It is seen that there is considerable variation in the amount of smut in the different plots. The common seed gave the largest per cent. of smut, the light seed the least, while the heavy seed gave a percentage about midway between the two.

VARIATION IN AMOUNT OF SMUT UNACCOUNTED FOR.

It should be added also that our observations show that there is considerable variation unaccounted for, in the amount of smut from year to year. Jensen has likewise noticed * a variation of the same kind.

HIDDEN SMUT.

While making the counts in the plots of the single-plant variety tests it was found (by a student, G. F. Ingram) that many heads having nearly or quite the normal appearance, were nevertheless smutted. The smut

* J. L. Jensen, Ueber die Verhütung des Kornbrandes, (März 1890) Kjöbenhavn, S. 6.

could be positively detected only by cutting open the husks. In this *hidden* smut, as it may be called, the outer glumes are of the usual size and shape, and quite sound. Usually but one grain is developed; its hulls are sound and tightly closed; the grain is smaller than usual. A rudimentary grain is usually produced on its furrowed (inner) side, and this from the exterior usually shows the smut. Upon forcing open the husks the larger grain is found to be more or less completely destroyed by smut.

This hidden smut was found only in a few varieties, as indicated by the tabular statement which here follows:

Plot	Name of Variety.	Smutted heads found by ordinary search by Farm Dept.	Smutted heads found by careful search by Botanical Dept.
7	Black Prolific	21	86
14	Canadian Triumph	30	88
38	New Swedish	43	77
50	Rennie's Prize White	168	257
53	Scottish Chief	13	34
62	Welcome	64	83
70	White Swede	110	149

The much smaller number of smutted heads found, as shown in the above table, by ordinary examination than by *critical search*, indicates the obscurity of the smut and the difficulty of estimating correctly the percentage when the smut is thus partly concealed. However, by careful inspection, marks or characters, though rather obscure, may yet be detected by which heads attacked with the hidden smut may be recognized even without dissection. (1) They are usually greener in color and lack the yellowish tinge of ripening heads that are sound. (2) The tips of the outer glumes are usually bleached, while the bases are a deep green. (3) Ordinarily some of the grains, especially the lower ones, are stunted and very evidently smaller, and especially narrower than healthy ones.

Microscopic examination showed that the spores in the hidden smut from Canadian Triumph (plot 14), Welcome (plot 62), and White Swede (plot 70), are all smooth, and apparently belong to the form named by us in II Annual Report (pp. 259–261), var. *levis*. The spores were sometimes found to be partially immature or poorly developed, often also monstrous in form and size. But it should be remarked that the var. *levis*

is not always hidden smut; yet it never seemed to occur in the loosest form of smut.

An explanation of the occurrence of the hidden smut might possibly be found in the fact that the oat plant possesses unusual vigor, in a manner overcoming and stunting the smut plant, which is therefore kept in abeyance, and though entering the grain, does not completely consume or deform the same with its hulls.

Jensen * found in making some infection experiments that spores of hidden smut produced completely open smut. He says: "But in a second series of experiments, disinfected oat grains were completely covered with spores taken from smutted heads with intact husks. The most of the plants died, so that only 12 headed out; of these 2 were smutty plants with completely naked smut. There seems therefore to be only one kind of oat smut."

Specimens of hidden smut are shown in plate II. The head or panicle marked A, is sound above and smutted below, while B and C are sound throughout; D and E are wholly smutted. The two latter (D and E) appear darker in the plate, but in reality all the heads were nearly the same color. The panicle A furnishes the best case for comparison—the upper part being sound and the lower part infected.

EXPERIMENTS BY FARMERS IN PREVENTING SMUT IN OATS.

In the spring of 1890 several farmers about Manhattan treated their seed oats with hot water. Mr. J. M. Kimball placed his seed in two bushel sacks, leaving them in water at 132° F. for 15 minutes. He followed as closely as possible the directions given by the Botanical Department in Bulletin 8. One-half of the field was planted with untreated seed for comparison. Count 3 was made in this untreated portion and indicated 8.51 per cent. of smut. In the treated portion of the field there was scarcely any smut. Of 1,952 heads counted, 8, or .41 per cent., were smutted, and these 8 heads occurred at the edge adjoining the untreated portion of the field. They may possibly have come from smutty seeds that were accidentally blown into the field during seeding.

Mr. J. F. Swingle also treated his seed oats. He placed them in a wire bushel basket lined with wire screen (12 meshes to the inch). The basket was always filled entirely full. In accordance with Jensen's recommendation, published in *The Industrialist*, Vol. XV, No. 25, February 22, 1890, p. 97,† he treated his oats only 5 minutes in water at 132° F. No untreated seed was planted for comparison, but the seed was from the same field as that used by Mr. J. M. Kimball, and probably would

* [Peterson, J. P.?] Nye Forsög over Brand i Vaarsæden, in Landmands-Blade, 22 Aargang. Nr. 35, Den. 31, August, 1889. (Kjöbenhaven,) S. 587.

† Kellerman, Prof. W. A.: Prevention of Smut.

have produced about 8 per cent. of smut if it had not been treated. His treated seed produced some smut; of 2,323 heads counted, 38, or 1.63 per cent., were smutty.

The difference in the amount of smut in the two fields is without doubt due to the fact that Mr. Kimball treated his wheat 15 minutes, whereas Mr. Swingle immersed his but 5 minutes.

The Farm Department at the College treated the seed of 80 varieties of oats in the spring of 1890. In Bulletin 13 of this Station, p. 65, the following statement is made: "All of these varieties were treated by the 'Jensen method' as a preventive against the attacks of smut; that is, they were immersed in hot water at a temperature of 135° F. for eight minutes, and then dried in the air, before they were seeded. The result was very satisfactory. These varieties were practically free from smut, while oats not thus treated contained from 5 to 10 per cent. of smutted heads, and in a few instances, even a much higher per cent."

The amount of smut in these same varieties when untreated is shown in the table of the single-plant variety test, on pp. 96 and 97.

EXPERIMENTS BY THE BOTANICAL DEPARTMENT IN PREVENTING OAT SMUT IN 1890.

CHARACTER AND PREPARATION OF THE LAND.

The land used in our experiments was a short distance south of that used in 1889 and 1890 for experiments with wheat smut (see Bulletin 12, pp. 31 and 22). It was a fairly good upland loam that had been under cultivation many years. Last year it was occupied by hoed crops, corn and potatoes. The land was plowed and harrowed in March, 1890, and was in good condition.

PLANTING THE SEED.

A five-hoed one-horse drill, set to plant 10 pecks per acre, was used in seeding. In plots 1–230 the drill was run out and back on each plot, making them 6 feet wide. In plots 231–311 the drill was run through but once, making these 3 feet wide. The treated plots of any one day's planting were sown first, and after they were all planted the drill was filled and the untreated plots seeded. The drill was carefully cleaned after planting each treated plot. As the wind was often blowing strongly great care was exercised to prevent the grains from blowing to other plots. The drill was a very inferior one and often dropped the seed irregularly in spite of constant attention. In the table of results to follow, the imperfections of the seeding are indicated in the number of rows. Plots 1–230 should have 10 rows, and plots 231–311, 5. It must not be supposed that the yield was directly decreased by the amount that the drill failed to drop, since in many cases the plants were by the very imperfections of drilling given more room and enabled to grow better.

Plots 1–39 were planted March 22, 1890; plots 40–72, March 24; plots 73–175, March 25; plots 176–217, March 30; plots 219–230, April 5; plots 231–311, April 12.

The same variety of oats was used in all the plots, viz.: Red Winter obtained from the Farm Department. The seed used in plots 1–217 gave slightly less smut than that used in plots 219–311, which probably came from a more smutty field.

GROWTH OF THE CROP, AND HARVEST.

All the plots (1–217) planted in March grew well and made a good crop. Those planted in April, and especially those planted April 12, made a poor growth. Plots 1, 95 and 97 were much injured by the proximity of trees. Plots 223–226 and 231–245 were slightly injured by being shaded in the morning by a dense row of trees.

The oats were cut with a cradle about July 12. The bundles were stored in a vacant house near by until the number of sound and smutted heads could be determined, after which they were threshed separately with a small hand machine. The thresher did the work effectually. The grain was cleaned with a fanning-mill and then weighed. The threshing was not finished until December, 1890. The bundles were attacked by mice during their long storage, and the amount of grain destroyed varied probably from 0 to 4 per cent. of the total produced by the bundle.

MANNER OF TREATING THE SEED.

The oats were treated in quantities of about one quart, or somewhat less in some cases. The seed treated with hot water was placed in a basket or iron frame covered with wire screen (12 meshes to the inch) and immersed in water of the proper temperature for the required time, after which it was plunged in cold water. In some cases the seed was not cooled suddenly by cold water, but was piled up and allowed to cool gradually. In a few instances the seed used in the hot-water treatments had been previously soaked a number of hours in cold water.

The seed treated with chemicals was placed in a solution of the substance used, and was allowed to stand a number of hours (mostly 24). Usually the solution was thoroughly shaken several times during the time of treatment. This was done to secure a thorough mixing of the solution and its application to every grain. Usually the substances used in making the solutions were chemically pure, but the copper sulphate, potassium sulphide and sodium hyposulphite were the usual commercial article, and were of course more or less impure.

The solutions were all made up by weight, thus the expression "10 per cent. solution" means that 10 parts by weight were dissolved in 90 parts of water.

In some cases the grain was immersed for 5 or 10 minutes in lime water after being treated with the solution. The lime water was made by slaking 1 part of fresh lime in 9 parts of water.

In every instance cistern water was used in preparing the solutions. The grain was with a few exceptions dried in a large vacant room where it was shielded from the direct rays of the sun.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890.

No	Treatment.	No. of rows	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE. *	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
1	Hot water, 143.6° F. (62° C.) 3 min.....	8	141.87	1258	22	1.75	lbs. oz. 14½	lbs. oz. 1—15¾	bu. 8.50	lbs 585.94
2	Untreated.....	7	141.87	1781	171	9.60	1—13	2 11⅜	16.99	813.28
3	Hot water, 143 6° F. (62° C.), 5 min....	8½	141.87	3293	0	0	4	4—11¼	37.50	1410.94
4	Untreated.....	9	141.87	3013	233	7.73	3— 2	4— 5⅛	29.30	1296.09
5	Hot water, 141.8° F. (61° C.), 3 min....	8	141.87	2721	29	1.07	3—13	4— 7⅜	35.74	1347.66
6	Untreated.....	9	141.87	3774	355	9.41	4— ½	5— ½	37.79	1509.38
7	Hot water, 141.8° F. (61° C.), 5 min....	7½	141.87	3194	5	.16	3—12½	5— 3	35.45	1556.25
8	Untreated.....	8¾	141.87	3493	376	10.76	4— 3	5— ¼	39.26	1504.69
9	Hot water, 140° F. (60° C.), 3 min.....	9	141.87	3912	45	1.15	3—15	5—11⅛	36.92	1708.59
10	Untreated.....	10	141.87	4100	446	10.88	3—15	5— 3⅝	36.92	1567.97
11	Hot water, 140° F. (60° C.), 3 min.; previously soaked 1 hour.....	8½	141.87	3049	2	.07	4— 9	4— 9⅛	42.77	1371.09
12	Untreated.....	9	141.87	3508	354	10.09	4— 5	4—14½	40.43	1471.88
13	Hot water, 140° F. (60° C.), 5 min.....	10	141.87	3442	11	.32	5— 2	4—13¼	48.05	1448.44
14	Untreated.....	7½	141.87	3008	298	9.91	3—15½	5— ⅝	37.21	1511.72
15	Hot water, 140° F. (60° C.), 10 min.....	8½	141.87	3117	0	0	4— 9½	4—13⅝	43.07	1455.47
16	Untreated.....	8	141.87	3689	315	8.54	4— 4¼	5— 6⅞	40.14	1628.91
17	Hot water, 138.2° F. (59° C.), 3 min...	9	141.87	3605	92	2.66	5	5—12⅞	46.88	1741.41
18	Untreated.....	8½	141.87	2986	279	9.34	3— 9½	5—11¼	33.69	1710.94
19	Hot water, 138.2° F. (59° C.), 5 min....	8	141.87	2894	14	.48	4—11	4—12⅞	43.95	1441.41
20	Untreated.....	8	141.87	3430	297	8.66	4— 6	5— 1⅞	41.02	1535.16
21	Hot water, 138.2° F. (59° C.), 10 min...	8½	141.87	3527	0	0	4— 1½	6— 7½	38.39	1940.63
22	Untreated.....	8½	141.87	3320	269	8.10	4—12	5— 1¾	44.53	1532.81
23	Hot water, 138.2° F. (59° C.), 15 min...	8½	141.87	3116	0	0	4— 5	5— 8¼	40.43	1654.69
24	Untreated.....	8	141.87	3796	389	10.25	3—15	5— 9	36.92	1668.75
25	Hot water, 136.4° F. (58° C.), 3 min.....	9	141.87	3248	60	1.85	3— 6½	5—11⅞	31.93	1722.66
26	Untreated.....	8¼	141.87	2911	219	7.52	3— 4½	5— 9⅛	30.76	1659.38
27	Hot water, 136.4° F. (58° C.), 3 min.; previously soaked 3 hours.....	9¾	141.87	2953	0	0	4— 7½	5—11⅛	41.90	1708.59
28	Untreated.....	7¼	141.87	2862	278	9.71	3—15	4— 6⅞	36.92	1328.91
29	Hot water, 136.4° F. (58° C.), 5 min....	9	141.87	3584	14	.39	4— 5½	5— 4¼	40.72	1579.69
30	Untreated.....	9¼	141.87	3904	436	11.17	4— 6	4— 8¾	41.02	1357.03
31	Hot water, 136.4° F. (58° C.), 5 min.; previously soaked 3 hours.....	8	141.87	3209	12	.37	3— 8	4—13	32.81	1443.75
32	Untreated.....	9½	141.87	3451	480	13.91	3— 3	3—14⅝	29.88	1174.22
33	Hot water, 136.4° F. (58° C.), 10 min...	8¼	141.87	2630	0	0	2—14	3—13½	26.95	1446.09
34	Untreated.....	9¾	141.87	3609	481	13.33	4— 3	3—12¼	39.26	1129.69
35	Hot water, 136.4° F. (58° C.), 10 min....	9	141.87	3100	0	0	4— 5	4—12⅛	40.43	1427.34
36	Untreated.....	9¾	141.87	3073	386	12.56	3— 9	3— 3	33.04	956.25

* These amounts are too small by 2½% throughout the entire table; detected too late for correction.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890—CONTINUED.

No.	Treatment.	No. of rows	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
37	Hot water, 134.6° F.(57° C.), 3 min	9	141.87	2942	78	2.65	4 — $\frac{1}{2}$	3— $6\frac{3}{4}$	37.79	1026.56
38	Untreated	$9\frac{1}{2}$	141.87	2946	357	12.12	2—$14\frac{1}{2}$	3— $8\frac{1}{2}$	27.25	1059.38
39	Hot water, 134.6° F. (57° C.), 3 min.; previously soaked 3 hours.	$9\frac{1}{2}$	141.87	3613	0	0	3—13	3 $14\frac{3}{8}$	35.74	1174.22
40	Untreated	$9\frac{1}{2}$	141.87	2768	258	9.28	2— 8	3— $9\frac{1}{2}$	28.44	1071.09
41	Hot water, 134.6° F.(57° C.), 5 min	$9\frac{3}{4}$	141.87	2331	18	.77	2—13	2 —$14\frac{3}{4}$	26.37	876.56
42	Untreated	9	141.87	2505	325	12.97	2—11	3 — $5\frac{3}{8}$	25.20	1005.47
43	Hot water, 134.6° F.(57° C.), 5 min.; previously soaked 3 hours.	$9\frac{1}{2}$	141.87	3051	0	0	3— 0	4 — $7\frac{6}{8}$	28.13	1312.97
44	Untreated	8	141.87	2282	239	10.47	2—11	2—$15\frac{5}{8}$	25.20	892.97
45	Hot water, 134.6° F.(57° C.). 8 min.; previously soaked 3 hours.	$8\frac{1}{2}$	141.87	1847	0	0	2— 1	2— 7	19.34	731.25
46	Untreated	9	141.87	2110	259	12.27	1—$10\frac{1}{2}$	2—$11\frac{1}{8}$	15.53	808.59
47	Hot water, 134.6° F. (57° C.), 10 min	10	141.87	3093	0	0	3— 9	3—$12\frac{1}{2}$	33.40	1134.38
48	Untreated	$9\frac{3}{4}$	141.87	2963	367	12.39	2—14	3—$11\frac{3}{8}$	26.95	1113.28
49	Hot water, 134.6° F. (57° C.), 15 min	$9\frac{1}{2}$	141.87	2192	0	0	2— 2	2—10	19.92	787.50
50	Untreated	$9\frac{1}{2}$	141.87	2133	226	10.60	2— $4\frac{1}{2}$	2— $7\frac{3}{8}$	21.39	788.28
51	Hot water, 133.7° F. (56.5° C.), 3 min	$9\frac{1}{2}$	141.87	2166	92	4.25	1—15	2 $13\frac{3}{4}$	18 17	857.81
52	Untreated	9	141.87	1944	211	10.85	2—10	2— $3\frac{1}{8}$	24.61	660.94
53	Hot water, 133.7° F. (56.5° C.), 5 min	$9\frac{1}{2}$	141.87	2405	19	.79	1—$14\frac{1}{2}$	3— 5	17 87	993 75
54	Untreated	8	141.87	1571	183	11.64	1—$15\frac{1}{2}$	1—$14\frac{1}{8}$	18.46	567.19
55	Hot water, 133.7° F. (56.5° C.), 10 min	9	141.87	1893	5	.26	2— $5\frac{1}{2}$	2— $6\frac{7}{8}$	21.97	728.91
56	Untreated	$8\frac{1}{2}$	141.87	1826	210	11.13	2— 4	1—$15\frac{1}{8}$	21.09	585.94
57	Hot water, 133.7° F. (56.5° C.), 15 min	$8\frac{3}{4}$	141.87	2078	0	0	2—11	3— $\frac{5}{8}$	25.20	911 72
58	Untreated	$7\frac{1}{2}$	141.87	2130	234	10.99	2— 4	3— $6\frac{3}{4}$	21.09	1026.56
59	Hot water, 132.8° F. (56° C.), 3 min	8	141.87	2545	85	3.34	3— 1	3 $4\frac{1}{4}$	28.71	970 69
60	Untreated	8	141.87	2265	226	9.98	2—13	3— $5\frac{7}{8}$	26.37	1010.16
61	Hot water, 132.8° F. (56° C.), 5 min	$9\frac{1}{2}$	141.87	2340	28	1.02	2—$12\frac{1}{2}$	3—$13\frac{1}{4}$	26.07	1148 11
62	Untreated	9	141.87	2295	236	10.28	3— 0	2— $1\frac{3}{4}$	28.13	632 81
63	Hot water, 132.8° F. (56° C.), 5 min.; not cooled	$9\frac{1}{2}$	141.87	3051	13	.43	3— 5	5— $\frac{8}{8}$	31 06	1511 72
64	Untreated	9	141.87	2500	256	10.24	3— $1\frac{1}{2}$	2—$15\frac{7}{8}$	29.00	897.66
65	Hot water, 132.8° F. (56° C.), 10 min	$9\frac{1}{2}$	141.87	2877	2	.07	3— $3\frac{1}{2}$	3 $14\frac{5}{8}$	30.16	1174 22
66	Untreated	8	141.87	2455	253	10.30	2—$10\frac{1}{2}$	3— 6	24.90	1012 50
67	Hot water, 132.8° F. (56° C.), 10 min.; not cooled	9	141.87	2505	0	0	3— 7	3—$14\frac{1}{4}$	32.23	1167 19
68	Untreated	9	141.87	2455	264	10.75	2— $7\frac{1}{2}$	3— $2\frac{5}{8}$	23.15	944.53
69	Hot water, 132.8° F. (56° C.), 15 min	$9\frac{1}{2}$	141.87	2830	0	0	3—$14\frac{1}{2}$	3— $2\frac{7}{8}$	36.62	953.91
70	Untreated	$8\frac{1}{2}$	141.87	2638	300	11.37	2—$14\frac{1}{2}$	3— $10\frac{7}{8}$	27.25	1094 53
71	Hot water, 131.9° F. (55.5° C.), 3 min	$8\frac{1}{2}$	141.87	2651	128	4.83	3—12	3— $3\frac{5}{8}$	35 16	963 28
72	Untreated	9	141.87	3040	314	10.33	3— 2	3 —$11\frac{3}{8}$	29.30	1113 28

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890—CONTINUED.

No.	Treatment.	No. of rows.	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
73	Hot water, 131.9° F. (55.5° C.), 5 min.	9¼	141.87	2568	50	1.94	3— 0	3—14½	28 13	1171 88
74	Untreated	10	141.87	3679	379	10.30	3— 8	4— 1¼	32.81	1396.88
75	Hot water, 131.9° F. (55.5° C.), 10 min.	9¾	141 87	2913	9	.31	4— 0	2—15	37.50	881.25
76	Untreated	8½	141.87	3005	285	9.48	3— 4½	3— 1½	30.76	909.38
77	Hot water, 131.9° F. (55.5° C.), 15 min.	8	141.87	2580	0	0	2— 7	4 4⅝	22.85	1286.72
78	Untreated	9	141.87	3011	311	10.33	3— 7	3— 1¼	32.23	923.44
79	Hot water, 131° F. (55° C.), 3 min.	10	141.87	3310	171	5.17	4— 4½	3— 3¼	40.14	960 94
80	Untreated	9	141.87	3109	333	10.71	2—12½	3— 8	26.08	1050 00
81	Hot water 131° F. (55° C.), 3 min.; previously soaked 8 hours.	9	141.87	2813	4	.14	3 - 6	3— 9⅜	31.64	1075.78
82	Untreated	9	141.87	2450	274	11.18	3— 1½	3— 8	29.00	1050.00
83	Hot water, 131° F. (55° C.), 5 min.	9	141.87	3546	90	2.54	4— 3	3—13⅜	39.26	1150.78
84	Untreated	8½	141.87	2356	251	10.65	3— 3	2— 9	29.88	768.75
85	Hot water, 131° F. (55° C.), 5 min.	8	141.87	2462	9	.37	3—10	3— 5⅜	33.99	1005.47
86	Untreated	8½	141.87	3092	312	10.09	3— 9	3— 7⅜	33.40	1038.28
87	Hot water, 131° F. (55° C.), 5 min.; previously soaked 8 hours.	7	141.87	2582	0	0	3— 5	4— 8¼	31.06	1354.69
88	Untreated	9	141.87	3182	375	11.79	2—11	4— 8⅜	25.20	1357.03
89	Hot water, 131° F. (55° C.), 10 min.	9½	141.87	2892	16	.55	4— 4½	4— 8⅝	40.14	1361.72
90	Untreated	10	141.87	3444	379	11.00	4—12	4— 6⅞	44.53	1328.91
91	Hot water, 131° F. (55° C.), 10 min.; not cooled	9	141.87	2460	0	0	2—14½	4— 8¼	27.25	1354.69
92	Untreated	10	141.87	3660	465	12.70	2—12½	4— 1	26.08	1218.75
93	Hot water, 131° F. (55° C.), 10 min.; previously soaked 8 hours.	10	141.87	2409	0	0	2—14	3— 1⅝	26.95	930.47
94	Untreated	8½	141.87	2300	255	11.09	1— 8	3— 3¼	14.06	960.94
95	Hot water, 131° F. (55° C.), 15 min.	7¼	141.87	1825	0	0	2— 2	2— 8⅜	19.92	757.03
97	Hot water, 129.2° F. (54° C.), 3 min.	10	141.87	2543	113	4.44	2— 7	2—11⅜	22.85	808.59
98	Untreated	9¾	141.87	2986	333	11.15	2— 6	3— 1	22.27	918.75
99	Hot water, 129.2° F. (54° C.), 3 min.; previously soaked 5 hours.	10	141.87	2345	0	0	2— 8	3—12⅜	23.44	1127.34
100	Untreated	10	141.87	3257	346	11.62	2— 8½	3— 9⅝	28.73	1080.47
101	Hot water, 129.2° F. (54° C.), 5 min.	9½	141.87	3435	97	2.82	4— 8	4— ¼	42.19	1204.69
102	Untreated	9¾	141.87	3775	365	9.67	4— 8	3—14⅜	42.19	1169.53
103	Hot water, 129.2° F. (54° C.), 5 min.; not cooled	9½	141.87	3131	16	.51	4— 2½	4—12⅞	38.97	1441.41
104	Untreated	9	141.87	3258	350	10.74	2— 2	5— ⅜	19.92	1507.03
105	Hot water, 129.2° F. (54° C.), 5 min.; previously soaked 5 hours.	9¼	141.87	2750	0	0	4— 4	3— 5⅛	39.84	996.09
106	Untreated	9½	141.87	2700	221	8.19	3— 8½	4— 2½	30.18	1246.88
107	Hot water, 129.2° F. (54° C.), 10 min.	10	141.87	2995	19	.63	3— 1	4— 3¼	28.71	1270.31
108	Untreated	9	141.87	2689	268	9.97	2—13½	3— 2⅞	26.66	953.91
109	Hot water, 129.2° F. (54° C.), 10 min; not cooled	9¾	141.87	2756	0	0	3— 7	4— 2⅝	32.23	1249.22

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890 - CONTINUED.

No.	Treatment.	No. of rows.	Size of plot in sq ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
110	Untreated	9	141.87	2645	325	12.29	2—14	4—15½	26.95	1490.63
111	Hot water, 127.2° F. (54° C.), 15 min.	10	141.87	3443	0	0	4— 2	4— 1⅛	38.67	1262.34
112	Untreated	9	141.87	2775	258	9.30	2—12½	3— 7⅝	26.08	1042.97
113	Hot water, 127.4° F. (53° C.), 5 min.	10	141.87	3100	45	1.45	4— 3	2—13½	39.26	853.13
114	Untreated	9½	141.87	2764	296	10.71	2— 4½	3— 7½	21.39	1040.63
115	Hot water, 127.4° F. (53° C.), 5 min.; previously soaked 5 hours	10	141.87	2788	0	0	2—15	3— 9⅜	27.54	1075.78
116	Untreated	10	141.87	3123	296	9.48	2—10½	3— 2⅝	20.90	944.53
117	Hot water, 127.4° F. (53° C.), 10 min.	10	141.87	2782	13	.47	2—13½	2—11⅜	26.66	808.59
118	Untreated	10	141.87	2300	224	9.74	2—14	2—10⅜	26.95	803.91
119	Hot water, 127.4° F. (53° C.), 10 min.; previously soaked 5 hours	10	141.87	2258	0	0	3— 6	3— 2⅝	31.64	953.91
120	Untreated	8	141.87	2654	248	9.34	2— 8	2—11½	28.44	815.63
121	Hot water, 127.4° F. (53° C.), 15 min.	10	141.87	2948	2	.07	3—10	3— 8⅛	33.99	1059.38
122	Untreated	9	141.87	*	.....	.....	2— 8	2— 9½	23.44	773.44
123	Hot water, 127.4° F. (53° C.), 20 min	10	141.87	3050	0	0	4— 0	3— 4½	37.50	984.38
124	Untreated	9	141.87	2590	260	10.04	2—10½	3— 3⅛	24.90	958.59
125	Hot water, 125.6° F. (52° C.), 5 min.	10	141.87	2735	63	2.30	3—14½	3—10½	36.62	1096.88
126	Untreated	9¼	141.87	3625	325	8.96	3— 9½	4— 3⅜	33.69	1263.28
127	Hot water, 125.6° F. (52° C.), 10 min.	10	141.87	2625	21	.80	4— 0	3—10¾	37.50	1101.56
128	Untreated	10	141.87	3451	320	9.21	3— 6	3—15⅜	31.64	1195.31
129	Hot water, 125.6° F. (52° C.), 10 min.; not cooled	10	141.87	2828	5	.18	4— ½	4— ⅞	37.79	1216.41
130	Untreated	9	141.87	3279	315	9.61	3—15½	4— 2	37.21	1237.50
131	Hot water, 125.6° F. (52° C.), 15 min.	9½	141.87	3036	3	.10	4— 6	4— 2	41.02	1237.50
132	Untreated	10	141.87	3331	328	9.85	4— 9	4— 5	42.77	1293.75
133	Hot water, 125.6° F. (52° C.), 20 min.	10	141.87	3043	0	0	5— 4	4—11½	49.22	1415.63
134	Untreated	10	141.87	3472	351	10.11	4— 7½	4— 7⅝	41.90	1338.28
135	Hot water, 123.8° F. (51° C.), 10 min.	10	141.87	3331	36	1.08	4— 2	4—11¾	38.67	1420.31
136	Untreated	9½	141.87	3915	335	8.56	4— 2½	4—11⅜	38.97	1421.87
137	Hot water, 123.8° F. (51° C.), 10 min.	9¾	141.87	3157	1	.03	4—11	4—10⅝	43.95	1399.22
138	Untreated	9½	141.87	3112	263	8.45	3—13½	4— 8½	36.04	1359.38
139	Hot water, 123.8° F. (51° C.), 20 min.	10	141.87	2840	7	.25	4— 2	3—15¾	38.67	1195.31
141	Hot water, 122° F. (50° C.), 10 min.	9	141.87	2683	30	1.12	4— 6½	3—13⅛	41.30	1146.09
142	Untreated	10	141.87	3135	303	9.67	3—15	3—15⅜	36.92	1195.31
143	Hot water, 122° F. (50° C.), 10 min.; not cooled	9	141.87	2879	22	.76	4—10½	4— 9¼	43.65	1373.44
144	Untreated	10	141.87	3230	252	7.80	4—10½	4— 5⅞	43.65	1310.16
145	Hot water, 122° F. (50° C.), 15 min.	9½	141.87	2585	40	1.55	4— 6	4— 3¾	41.02	1270.31

* By accident this plot was not counted.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890—CONTINUED.

No.	Treatment.	No. of rows.	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
146	Untreated	9¼	141.87	3887	357	9.30	4— 3½	4— 9⅛	39.55	1371.09
147	Hot water, 122 F. (50 C.), 20 min.	9¾	141.87	2508	7	.28	4— 4	3— 6⅜	39.84	1019.53
148	Untreated	9¾	141.87	3219	307	9.54	3—13	3—14	35.74	1162.50
149	Hot water, 120.2 F. (49 C.), 10 min.	10	141.87	2815	44	1.56	3—12	4— 6⅜	35.16	1324.22
150	Untreated	10	141.87	3859	324	8.40	4— 3	4— 13½	39.26	1232.81
151	Hot water, 120.2 F. (49 C.), 15 min.	10	141.87	3115	31	.10	5— 4	4— 6⅞	49.22	1328.91
152	Untreated	10	141.87	2950	187	6.34	4— 2	4— 6	38.07	1312.50
153	Hot water, 120.2 F. (49 C.), 20 min.	9¼	141.87	3011	11	.37	4— 2½	4— 9⅜	38.97	1375.78
154	Untreated	8½	141.87	2630	185	7.03	3— 5	3— 7½	31.06	1040.63
155	Potassium sulphide, ¾% solution, 24 hours	9¾	141.87	1950	0	0	3— 3½	3— 9½	30.18	1078.13
156	Untreated	10	141.87	2800	261	9.32	2—13	4— ⅛	26.37	1202.34
157	Potassium sulphide, ½% solution, 24 hours	10	141.87	2047	0	0	4— 3	4— 1⅜	39.26	1230.47
158	Untreated	10	141.87	2661	153	5.75	3— 4	3—12½	30.47	1134.38
159	Potassium sulphide, ¼% solution, 24 hours	9¾	141.87	2553	3	.12	3—13	.....	35.74	.....
160	Untreated	10	141.87	2780	228	8.2	3— 8½	3—11⅜	33.11	1113.28
161	Sodium hyposulphite, 9/10% solution, 24 hours	10	141.87	2380	35	1.47	3—14	4— 2⅜	36.33	1244.53
162	Untreated	10	141.87	2660	269	10.11	3—13½	2— 3¾	36.04	670.31
163	Sodium hyposulphite, 4/5% solution, 24 hours	9½	141.87	2154	80	3.71	2—14	3— 2¼	26.95	942.19
164	Untreated	8½	141.87	2410	180	7.47	3— 3½	3— 6⅝	30.18	1024.22
165	Sodium hyposulphite, 2½% solution, 24 hours	10	141.87	1800	161	8.94	2— 8	3—10⅞	23.41	1103.91
166	Untreated	9	141.87	1762	149	8.46	2—11½	3— 2¾	25.49	951.56
167	Sodium hyposulphite, 7/10% solution, 24 hours	9	141.87	1814	159	8.77	2— 1	3— 0	19.34	900.00
168	Untreated	8½	141.87	2600	235	9.04	2—11½	4— 5⅜	25.49	1305.47
169	Copper sulphate, 1/10% solution, 24 hours, limed	9½	141.87	2045	38	1.86	2— 7½	3— 5½	23.15	1003.13
170	Untreated	10	141.87	3048	244	8.01	3—10	3— 9½	33.99	1078.13
171	Copper sulphate, ½% solution, 24 hours	9	141.87	1620	0	0	2— 8½	2— 4½	23.73	684.38
172	Untreated	10	141.87	2681	248	9.25	2—13	3— 5	28.37	993.75
173	Copper sulphate, 9/10% solution, 24 hours	8	141.87	1641	4	.24	1—14½	3— 8⅜	17.87	1057.03
174	Untreated	10	141.87	2666	267	10.04	2—11	3—15⅜	25.20	1188.28
175	Copper sulphate, 4½% solution, 24 hours	10	141.87	930	0	0	1—11	1— 6½	12.60	525.00
176	Untreated	10	141.87	2810	364	12.95	2—14	3— 4½	26.96	979.69
177	Copper sulphate, 7½% solution, 24 hours, limed	?	141.87	550	17	3.09	0— 5	0—12¾	2.93	239.06
178	Untreated	9	141.87	2265	344	15.19	2— 4	2— 8⅜	21.09	670.31
179	Copper sulphate, 9/10% solution, 24 hours	?	141.87	Destroyed by the treatment.						
181	Copper sulphate, 4½% solution,* 24 hours, limed	?	121.6	792	2	.25	1— 0	0—14½	10.94	317.19
182	Untreated	9	121.6	2042	325	15.92	1— 9	2— 4⅝	17.09	801.17

* Treated with the same solution that was used six days before in treating plot 175.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890—CONTINUED.

No.	Treatment.	No. of rows.	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads.	Smutted heads.	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
183	Copper sulphate, $\frac{2}{10}$% solution,* 24 hours	10	121.6	1030	5	.49	0—14½	2— 7½	9.91	864.06
184	Untreated	9½	121.6	1955	801	15.40	1—14	2— 6	20.51	831.25
185	Copper sulphate, ⅛% solution,† 24 hours, limed	10	121.6	1378	0	0	1—10	2— 8¼	17.77	880.47
186	Untreated	9	121.6	1558	208	13.35	1— 5½	2— 3½	14.70	776.56
187	Copper sulphate, $\frac{1}{10}$% solution,‡ 24 hours	9	121.6	1986	32	1.61	1—12	3 - 7⅝	19.14	1216 80
188	Untreated	9	121.6	1720	240	13.95	1— 2½	3— ⅞	12 65	1069.14
189	Copper nitrate, 5% solution, 24 hours.	?	121.6	731	1	.13	0— 8	1— 2⅜	5.47	401.95
190	Untreated	10	121.6	2114	346	16.37	2—11	1—14½	29.39	667.19
191	Copper nitrate, 5% solution, 24 hours, limed	?	121.6	175	1	.57	0— 6	0— 3	4.10	65.63
192	Untreated	9¾	121.6	1845	358	19.40	2— 1½	2—10¾	22.90	985.16
193	Copper nitrate, 2½% solution, 24 hours	9	121.6	894	0	0	0—14	1—10¾	9.57	585.16
194	Untreated	10	121.6	2187	362	16.55	1—13	2—15½	19.52	1083.59
195	Copper nitrate, 2½% solution, 24 hours, limed	?	121.6	394	0	0	0— 5½	0—11	3.76	240.63
196	Untreated	8¾	121.6	2280	333	14.61	2— 3	2— ⅞	23.93	719.14
197	Copper nitrate, 1% solution, 24 hours.	8¾	121.6	1127	7	.62	1— 5½	1 15¾	14.70	694.53
198	Untreated	4	121.6	1063	105	9.88	1— 7½	1— 6¾	16.06	497.66
199	Copper nitrate, 1% solution, 24 hours, limed	?	121.6	401	0	0	0— 5½	0— 6½	3.76	142 19
200	Untreated	9½	121.6	2080	303	14.57	2— ½	3— 1⅛	22.22	1080.08
201	Potassium sulphide, ¾% solution,§ 24 hours	9¾	121.6	1982	0	0	2—13½	2—10¾	31.10	935.16
202	Untreated	9	121.6	2186	319	14.59	2— 4	2—15⅜	24.61	1036.33
203	Potassium sulphide, ¼% solution,‖ 24 hours	9¾	121.6	2010	10	.5	2— 7½	2 14⅛	27.00	1008.98
204	Untreated	8½	121.6	1827	259	14.18	1— 5	3— 1¼	14.36	1077.34
205	Potassium sulphide, ½% solution,¶ 24 hours	9¾	121.6	1900	4	.21	2— 1½	2 -11¾	2.90	957.03
206	Untreated	10	121.6	1800	340	18.89	.....	.....	.....	.....
207	Soda (sodium hydrogen carbonate), 10% solution, 24 hours	9	121.6	1850	80	4.32	2— 3½	2—14	24.27	1008 25
208	Untreated	10	121.6	2357	291	12.38	1—14	3— 5½	20.51	1170.31
209	Soda (sodium hydrogen carbonate), 5% solution, 24 hours	?	121.6	1445	79	5.47	2— 3	2— 3¾	23.93	782.03
210	Untreated	9	121.6	2097	276	13.16	1—14	3— 7½	20.51	1214.06
211	Soda (sodium hydrogen carbonate), 1% solution, 24 hours	9	121.6	1800	145	8.06	2— 2	2— 9¼	23.24	902.34
212	Untreated	9	121.6	2500	300	12	2— 7	4— 1¾	26.66	1488.28
213	Sodium hyposulphite, $\frac{2}{10}$% solution, 24 hours	9½	121.6	1925	11	.57	1—12½	4—13⅜	19.48	1692 58

* The same solution that was used 6 days before to treat the seed for plot 173.
† The same solution that was used 6 days before in treating the seed for plot 171.
‡ Treated with the same solution that was used 6 days before to treat the seed for plot 169.
§ The same solution had been used 6 days before to treat the seed for plot 155.
‖ The same solution that was used 6 days before to treat the seed for plot 159.
¶ The same solution was used in treating the seed for plot 157. The solution had been kept in a tin vessel, and had apparently undergone a chemical change, as it was of a very dark color. Apparently all of the potassium sulphide solutions had decomposed more or less since first used.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890 CONTINUED.

No.	Treatment.	No. of rows.	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain.	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
214	Untreated	8½	121.6	2592	295	11.38	2— 2	4— 6⅞	23.24	1550.39
215	Sodium hyposulphite, 4⅔% solution, 24 hours	9¼	121.6	1638	24	1.47	2— 4	3— 8[illegible]	24.61	1227.73
216	Untreated	9	121.6	1944	225	11.57	2— 4	3—12	24.61	1312.50
217	Sodium hyposulphite, 2⅔% solution, 24 hours	9	121.6	2078	49	2.36	2 -11½	3 -13½	29.74	1345 31
218	Untreated	?	121.6	1427	172	12.12	1—10	2—11⅛	17.77	951.56
219	Sodium hyposulphite, $\frac{9}{10}$% solution, 24 hours	8	121.6	704	37	5.26	1— 1½	0—15⅝	11.96	347.27
220	Untreated	8	121.6	1283	204	15.9	1—13½	2—10¼	20.17	924.22
221	Lime water in which copper sulphate had been neutralized, 24 hours	6½	121.6	1057	6	.57	1— 7	1—15⅛	15.72	680.86
222	Untreated	5½	121.6	1380	132	9.58	1— 4½	2—11¼	14.01	946.09
223	Winter oats from plot I (4.67% smutted in 1889)*	8	100.14	1457	125	8.55	1—11	1—11⅞	22.41	740.43
224	Untreated	7½	100.14	1552	178	11.47	2— 5½	2—12⅜	31.13	1178.71
225	Winter oats from plot II (no smut in 1889)	9	100.14	1400	28	2	1—10½	2—15¼	22.00	1255.08
226	Untreated	6	100.14	882	109	12.36	1— 8½	1—15	20.34	823.44
227	Winter oats from plot III (8.11% smutted in 1889	9	121.6	2400	245	10.21	2— 4	2— 7⅞	24.61	872.27
228	Untreated	7½	121.6	1806	301	17.17	2— 9	2— 7⅜	28.03	861.33
229	Winter oats from field surrounding plots I-II	9½	121.6	1790	186	10.39	2— 9½	2—14½	28.37	1017.19
230	Untreated	7½	121.6	2577	216	8.38	3— 2	4— 3⅛	34.18	1468.36
231	Verdigris, 5% solution, 24 hours	?	50.07	48	2	4.17	0— ½	0— 2	.83	106.25
232	Untreated	4½	50.07	860	111	12.9	0—14½	1— 9⅝	24.07	1361.33
233	Verdigris, 2% solution, 24 hours	?	50.07	32	0	0	0— ¼	0— ⅝	.42	46.48
234	Untreated	5	50.07	1100	90	8.18	.....	.....	.....	.....
235	Copper nitrate, 5% solution, † 18 hours	?	50.07	10	0	0	0— ⅛	0— ⅜	.21	19.92
236	Untreated	5	50.07	1240	92	7.42	1— 4	1—15⅝	33.20	1630.08
237	Copper nitrate, 1% solution, ‡ 18 hours	?	50.07	140	0	0	0— ½	0— 4⅛	.83	232.42
238	Untreated	5	50.07	1062	173	16.29	1— 2½	1—12⅜	30.71	1507.42
239	Soda (sodium hydrogen carbonate) 10% solution, 16 hours	4	50.07	683	8	1.17	1— ½	1— 6	27.39	1168.75
240	Untreated	5	50.07	1094	112	10.24	0— 7½	2— 6	12.45	2018.75
241	Sodium sulphate, 5% solution, 20 hours	5	50.07	693	71	10.25	.....	.....	.....	.....
242	Untreated	4	50.07	1085	168	15.48	1— 1½	1—14⅝	29.05	1626.95
243	Potassium sulphate, 1% solution, † 24 hours	4	50.07	787	58	7.37	0 15	1— 9⅜	24.90	1848.05
244	Untreated	5	50.07	1222	143	11.7	0—15½	1— 2⅜	25.73	976.17
245	Corrosive sublimate (mercuric chloride), 1% solution, § 24 hours,	?	50.07	105	0	0	0— ⅜	0— 4⅛	1.45	219.14

* The seed used in plots 223, 225, 227 and 229 was from the experimental plots and field on J. F. Swingle's farm, in 1889. For an account of these plots see Bulletin No. 8 of this station, pp 95, 96, and Second Annual Report of this station, pp 246-248.

† Treated with the same solution that was used 10 days before in treating the seed for plot 189.

‡ Treated with the same solution that was used 10 days before to treat seed for plot 197.

Dried in bright sunlight.

§ The solution was kept in tin vessel, consequence turned black. Probably suffered chemical changes.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890—CONTINUED.

No.	Treatment.	No. of rows.	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
246	Untreated	5	50.07	1205	116	9.63	1— 1½	1—11	29.05	1434.38
247	Corrosive sublimate (mercuric chloride), $\frac{1}{10}$% solution, 24 hours.	5	50.07	363	1	.28	0 – 6½	0 –11½	10.79	591.02
248	Untreated	4¾	50.07	1042	96	9.21	1—11	1— 2	35.69	1248.42
249	Copper nitrate, 5% solution, 2 h'rs; previously soaked 24 hours	?	50.07	Totally destroyed by the treatment.						
250	Untreated	5	50.07	942	92	9.77	1— 2	1— 7¼	29.88	1235.16
251	Salicylic acid, conc. solution, 2 hours; previously soaked 24 hours,	?	50.07	69	0	0	0— 1	0— 1½	1.66	98.33
252	Untreated	5	50.07	1141	117	10.25	1— 0	1— 4¾	26.56	1108.98
253	Potassium bichromate, 10% solution, 23 hours	?	50.07	Totally destroyed by the treatment.						
254	Untreated	4½	50.07	602	70	11.63	0— 6	0–10⅞	9.96	577.13
255	Potassium bichromate, 5% solution, 9 hours	2	50.07	109	0	0	0 1½	0 – 1⅞	2.49	73.05
256	Untreated	4	50.07	724	63	8.70	0–12½	0—14¾	20.75	783.59
257	Potassium bichromate, 1% solution, 9 hours	4	50.07	404	4	.99	0— 5	0 –11⅞	8.30	604.30
258	Untreated	5	50.07	839	93	11.08	0–13	0—15¾	21.58	829.68
259	Carbon bisulphide vapor, 15 hours	5	50.07	579	46	7.94	0 – 9	1 – 1⅝	14.94	930.47
260	Untreated	4½	50.07	1089	106	9.73	0–12	1— 7⅜	19.92	1194.53
261	Ammonium hydrate vapor, 36 hours.	?	50.07	Totally destroyed by the treatment.						
262	Untreated	5	50.07	1087	112	10.3	0–13	1–10½	21.58	1407.81
263	Ammonium hydrate vapor, 3 hours	5	50.07	1032	82	7.95	0–12	1—15½	19.92	1673.44
264	Untreated	5	50.07	927	79	8.52	0–12½	1— 5¾	20.75	1155.47
265	Chloroform vapor, 24 hours	5	50.07	882	82	9.3	0–12	1— 3⅝	19.92	1042.58
266	Untreated	5	50.07	576	81	14.06	0— 5	0—13½	8.30	717.19
267	Verdigris, 5% solution, 19 hours	?	60.8	Totally destroyed by the treatment.						
268	Untreated	4¾	60.8	1311	180	13.73	1–12	1—14½	38.28	1334.37
269	Verdigris, 2% solution, 19 hours	?	60.8	65	0	0	0— ½	0— 2½	.68	92.97
270	Untreated	5	60.8	1552	180	11.60	1— 8½	1—15⅝	33.50	1372.65
271	Copper nitrate, 2½% solution, 18 hours	?	60.8	24	0	0	0— ¼	0— ½	.31	21.87
272	Untreated	5	60.8	1366	156	11.42	1— 9	1— 7⅜	34.18	1044.53
273	Soda (sodium hydrogen carbonate), 10% solution, 24 hours	3¾	60.8	640	4	.63	0–11½	1 – 6⅛	19.82	967.97
274	Untreated	4¾	60.8	1249	164	13.13	1— 1	1–10¾	23.24	1170.31
275	Soda (sodium hydrog'n carb'nate) 1% sol. 21 hours; then emersed 2 min. in copper sulphate, 10% sol.,	?	60.8	Totally destroyed by the treatment.						
276	Untreated	5	60.8	1270	169	13.39	1— 2½	1—11⅛	25.20	1186.72
277	Sodium sulphate, 1% solution, 22 hours	5	60.8	810	50	6.17	1 – 2	1 – 9⅝	24.61	1121.09
278	Untreated	5	60.8	1329	169	12.72	1— 6	1— 9⅞	30.08	1132.03
279	Potassium sulphate, 1% solution, 9 hours	5	60.8	1058	141	13.33	0–12½	1—15⅞	17.09	1394.53
280	Untreated	5	60.8	1410	178	12.62	1— 6	2— 1¼	30.08	1454.69
281	Corrosive sublimate (mercuric chloride), 1% solution*, 9 hours	5	60.8	697	4	.57	0— 8½	1— 7	11.62	1006.25

* See note to plot 245.

TABULATION OF EXPERIMENTS IN PREVENTING OAT SMUT IN 1890—CONCLUDED.

No.	Treatment.	No. of rows.	Size of plot in sq. ft.	ACTUAL YIELD PER PLOT.					CALCULATED YIELD PER ACRE.	
				Total heads	Smutted heads	Per cent. smutted.	Grain.	Straw.	Grain	Straw.
							lbs. oz.	lbs. oz.	bu.	lbs.
282	Untreated	5	60.8	1491	171	11.47	1— 3½	2— 4	26.66	1575.00
283	Corrosive sublimate, (mercuric chloride,) $\frac{1}{10}$% solution, 2 hours; previously soaked 24 hours	4	60.8	775	2	.26	1— ½	1— 4⅞	22.56	913.28
284	Untreated	4¾	60.8	967	66	6.83	0—11½	1— 2¼	15.72	798.44
285	Mixture of equal parts of copper sulphate 10% solution and soda 5% solution, 2 hours; previously soaked 24 hours	?	60.8	Totally destroyed by the treatment.						
286	Untreated	5	60.8	938	128	13.65	0—15	1— 5¾	20.51	951.56
287	Soaked 24 hours in cistern water	5	60.8	830	65	7.83	0—15½	1— 3	21.19	831.25
288	Untreated	5	60.8	1005	158	15.72	0—12	1— 1⅝	16.41	771.09
289	Potassium bichromate, 5% solution, 24 hours	3	60.8	306	4	1.3	0— 4	0— 6	5.47	262.50
290	Untreated	4	60.8	772	103*	13.35	0—11½	1— 1⅝	15.72	771.09
291	Potassium bichromate, 1% solution,* 24 hours	4	60.8	816	0	0	0— 9	1— 3½	12.31	853.12
292	Untreated	4	60.8	700	95	13.57	0—11½	2— ½	15.72	1421.87
293	Carbon bisulphide vapor, 36 hours	5	60.8	550	96	17.45	0— 4½	0—12½	6.15	546.87
294	Untreated	4	60.8	475	61	12.84	0— 6	0—11⅞	8.20	519.53
295	Carbon bisulphide vapor, 3 hours	4	60.8	633	70	11.06	0— 9½	1— ¼	12.99	710.94
296	Untreated	5	60.8	1040	95	9.13	0—12½	1— 6¾	17.09	995.31
297	Ammonium hydrate vapor, 15 hours,	?	60.8	72	0	0	0— ½	0— 1⅞	.68	82.03
298	Untreated	5	60.8	1038	136	13.1	0— 8½	1—12⅜	11.62	1241.40
299	Chloroform vapor, 48 hours	4	60.8	969	105	10.84	0—12	1— 3	16.41	831.25
300	Untreated	4¾	60.8	741	47	6.34	0— 9	1— 7⅜	12.30	1022.65
301	Chloroform vapor, 3 hours	5	60.8	918	108	11.76	0—11	1—11½	15.04	1203.12
302	Untreated	5	60.8	1042	132	12.66	0—10	1— 8¼	13.67	1060.94
303	Ether vapor, 36 hours	4½	121.6	627	80	12.76	0— 4	0—13¼	2.73	289.84
304	Untreated	4½	121.6	484	81	16.74	0— 4½	0— 8	3.08	175.00
305	Ether vapor, 15 hours	5	121.6	638	90	14.11	0—10	1— ½	6.84	360.94
306	Untreated	4½	121.6	807	161	19.95	0— 9	1— ¾	6.15	366.41
307	Ether vapor, 3 hours	4	121.6	698	95	13.61	0— 8	0—13¼	5.47	289.84
308	Untreated	3	121.6	521	79	15.16	0— 7½	1— 6½	5.13	492.19
309	Castile soap, 10% solution, 24 hours, washed after treatment	5	121.6	270	6	2.22	0— 1½	0— 5⅞	1.03	128.52
310	Untreated	4	121.6	997	166	16.65	0—10	1— 1¼	6.84	377.34
311	Castile soap, 10% solution, 24 hours	5	121.6	477	0	0	0— 4½	0—11½	3.08	243.34

* Dried in bright sunlight.

THE MORE IMPORTANT RESULTS SHOWN IN THE PRECEDING TABLE.

I.

The following 26 treatments destroyed *all* the smut and gave a yield of grain greater than the average of the two adjacent untreated plots. All except 23, 35, 43, 99, 155 and 185 gave an increase in yield greater than the amount that would result from replacing the smutted heads of the untreated plots with sound ones.

3, Hot water, 143.6° F. (62° C.), 5 minutes.
15, Hot water, 140° F. (60° C.), 10 minutes.
23, †Hot water, 138.2° F. (59° C.), 15 minutes.
27, Hot water, 136.4° F. (58° C.), 3 minutes; previously soaked 3 hours.
35, †Hot water, 136.4° F. (58° C.), 10 minutes.
39, Hot water, 134.6° F. (57° C.), 3 minutes; previously soaked 3 hours.
43, †Hot water, 134.6° F. (57° C.), 5 minutes; previously soaked 3 hours.
47, Hot water, 134.6° F. (57° C.), 10 minutes.
57, Hot water, 133.7° F. (56.5° C.), 15 minutes.
67, Hot water, 132.8° F. (56° C.), 10 minutes; not cooled.
69, Hot water, 132.8° F. (56° C.), 15 minutes.
87, *Hot water, 131° F. (55° C.), 5 minutes; previously soaked 8 hours.
93, Hot water, 131° F. (55° C.), 10 minutes; previously soaked 8 hours.
95, Hot water, 131° F. (55° C.), 15 minutes.
99, *†Hot water, 129.2° F. (54° C.), 3 minutes; previously soaked 5 hours.
105, Hot water, 129.2° F. (54° C.), 5 minutes; previously soaked 5 hours.
109, Hot water, 129.2° F. (54° C.), 10 minutes; not cooled.
111, Hot water, 129.2° F. (54° C.), 15 minutes.
115, Hot water, 127.4° F. (53° C.), 5 minutes; previously soaked 5 hours.
119, Hot water, 127.4° F. (53° C.), 10 minutes; previously soaked 5 hours.
123, Hot water, 127.4° F. (53° C.), 20 minutes.
133, Hot water, 125.6° F. (52° C.), 20 minutes.
155, *†Potassium sulphide, ¼% solution, 24 hours.
157, Potassium sulphide, ½% solution, 24 hours.
185, *†Copper sulphate, ½% solution, 24 hours, limed.
201, Potassium sulphide, ¼% solution, 24 hours.

II.

The following 28 treatments decreased the amount of smut to less than 1 per cent. and gave a yield larger than the average of the two adjacent untreated plots. All except 29, 41, 55, 63, 85, 107, 117, 129, 139, 147 and 283 gave an increase in the yield greater than would be obtained by replacing the smutted heads of the untreated plots with sound ones.

11, Hot water, 140° F. (60° C.), 3 minutes; previously soaked 1 hour.
13, Hot water, 140° F. (60° C.), 5 minutes.
19, Hot water, 138.2° F. (59° C.), 5 minutes.
29, *†Hot water, 136.4° F. (58° C.), 5 minutes.

†These plots gave a less increase in yield than would be obtained by replacing the smutted heads of the untreated plots with sound ones.
*These plots were exceeded in yield by one of the adjacent untreated plots.

41, †Hot water, 134.6° F. (57° C.), 5 minutes.
55, †Hot water, 133.7° F. (56.5° C.), 10 minutes.
63, †Hot water, 132.8° F. (56° C.), 5 minutes; not cooled.
65, Hot water, 132.8° F. (56° C.), 10 minutes.
75, Hot water, 131.9° F. (55 5° C.), 10 minutes.
81, Hot water, 131° F. (55° C.), 3 minutes; previously soaked 8 hours.
85, †Hot water, 131° F. (55° C.), 5 minutes.
89, *Hot water, 131° F. (55° C.), 10 minutes.
103, *Hot water, 129.2° F. (54° C.), 5 minutes; not cooled.
107, *†Hot water, 129.2° F. (54° C.), 10 minutes.
117, *†Hot water, 127.4° F. (53° C.), 10 minutes.
121. Hot water, 127.4° F. (53° C.), 15 minutes.
127, Hot water, 125.6 F. (52° C.), 10 minutes.
129, Hot water, 125.6° F. (52° C.), 10 minutes; not cooled.
131, *†Hot water, 125.6° F. (52° C.), 15 minutes.
137, Hot water, 123.8° F. (51° C.), 10 minutes.
139, *†Hot water, 123.8° F. (51° C.), 20 minutes.
143, Hot water, 122° F. (50° C.), 10 minutes; not cooled.
147, †Hot water, 122° F. (50° C.), 20 minutes.
151, Hot water, 120.2° F, (49° C), 15 minutes.
159, Potassium sulphide, ½% solution, 24 hours.
203, Potassium sulphide, ½% solution, 24 hours.
205, Potassium sulphide, ½% solution, 24 hours.
283, *†Corrosive sublimate (mercuric chloride), $\frac{1}{10}$% solution, 2 hours; previously soaked 24 hours.

III.

The following 24 plots had from 1 to 14 per cent. of smutted heads and yet an increased yield as compared with the average of the two adjacent untreated plots. All but 5, 17, 161 and 215 gave an increase in yield greater than would occur if the smutted heads of the untreated plots were replaced with sound ones.

5, *†Hot water, 141.8° F. (61° C.), 3 minutes.
17, †Hot water, 138.2° F. (59° C.), 3 minutes.
37, Hot water, 134.6° F. (57° C.), 3 minutes.
59, Hot water, 132.8° F. (56° C.), 3 minutes.
71, Hot water, 131.9° F. (55.5° C.), 3 minutes.
79, Hot water, 131° F. (55° C.), 3 minutes.
83, Hot water, 131° F. (55° C.), 5 minutes.
97, Hot water, 129.2° F. (54° C.), 3 minutes.
101, Hot water, 129.2° F. (54° C.), 5 minutes.
113, Hot water, 127.4° F. (53° C.), 5 minutes.
125, Hot water, 125.6° F. (52° C.), 5 minutes.
141, Hot water, 122° F. (50° C.), 10 minutes.
161, †Sodium hyposulphite, $9\frac{2}{10}$% solution, 24 hours.
187, Copper sulphate, $\frac{1}{10}$% solution, 24 hours.
207, Soda (sodium hydrogen carbonate), 10% solution, 24 hours.

†These plots gave a less increase in the yield than would be obtained by replacing the smutted heads of the untreated plots with sound ones.
*These plots were exceeded in yield by one of the adjacent untreated plots.

209, Soda (sodium hydrogen carbonate), 5% solution, 24 hours.
215, †Sodium hyposulphite, 4⅕% solution, 24 hours.
217, Sodium hyposulphite, 2⅖% solution, 24 hours.
239, *Soda (sodium hydrogen carbonate), 10% solution, 16 hours.
265, *Chloroform vapor, 24 hours.
295, *Carbon bisulphide vapor, 3 hours.
299, Chloroform vapor, 48 hours.
301, Chloroform vapor, 3 hours.
305, Ether vapor, 15 hours.

IV.

The following 7 treatments destroyed all the smut and gave a yield nearly equal to the average of the two adjacent untreated plots.

3, Hot water, 143.6° F. (62° C.), 5 minutes.
21, Hot water, 138.2° F. (59° C.), 10 minutes.
45, Hot water, 134.6° F. (57° C.), 8 minutes; previously soaked 3 hours.
49, Hot water, 134.6° F. (57° C.), 15 minutes.
77, Hot water, 131.9° F. (55.5° C.), 15 minutes.
91, Hot water, 131° F. (55° C.), 10 minutes; not cooled.
171, Copper sulphate ½% solution, 24 hours.

V.

The following 8 plots had less than 1 per cent. of smutted heads and gave a yield nearly equal to the average of the two adjacent untreated plots.

7, Hot water, 141.8° F. (61° C.), 5 minutes.
31, Hot water, 136.4° F. (58° C.), 5 minutes; previously soaked 3 hours.
53, Hot water, 133.7° F. (56.5 C.), 5 minutes.
173, Copper sulphate, 1 1/10% solution, 24 hours.
197, Copper nitrate, 1% solution, 24 hours.
213, Sodium hyposulphite, 9 1/10% solution, 24 hours.
221, Lime water in which copper sulphate had been neutralized, 24 hours.
273, Soda (sodium hydrogen carbonate), 10% solution, 24 hours.

VI.

The following 7 plots gave over 1 per cent. smut, and a yield nearly equaling the average of the two adjacent untreated plots.

61, Hot water, 132.8° F. (56° C.), 5 minutes.
99, Hot water, 129.2° F. (54° C.), 3 minutes; previously soaked 5 hours.
135, Hot water, 123.8° F. (51° C.), 10 minutes.
145, Hot water, 122° F. (50° C.), 15 minutes.
149, Hot water, 120.2° F. (49° C.), 10 minutes.
211, Soda (sodium hydrogen carbonate), 1% solution, 24 hours.
243, Potassium sulphate, 1% solution, 24 hours.

The following 20 treatments nearly destroyed the grain, the yield being very much less than the average of the two adjacent untreated plots.

† These plots gave a less increase in yield than would be obtained by replacing the smutted heads of the untreated plots with sound ones.
* These plots were exceeded in yield by one of the adjacant untreated plots.

VII.

Having no Smut (13 Treatments).

193, Copper nitrate, 2½% solution, 24 hours.
195, Copper nitrate, 2½% solution, 24 hours; limed.
199, Copper nitrate, 1% solution, 24 hours; limed.
233, Verdigris, 2% solution, 24 hours.
235, Copper nitrate, 5% solution, 18 hours.
237, Copper nitrate, 1% solution, 18 hours.
245, Corrosive sublimate (mercuric chloride), 1% solution, 24 hours.
251, Salicylic acid, conc. solution, 2 hours; previously soaked 24 hours.
255, Potassium bichromate, 5% solution, 9 hours.
269, Verdigris, 2% solution, 19 hours.
271, Copper nitrate, 2½% solution, 18 hours.
297, Ammonium hydrate vapor, 15 hours.
311, Castile soap, 10% solution, 24 hours.

VIII.

Having Less Than 1% Smut (6 Treatments).

181, Copper sulphate, $4\frac{4}{5}$% solution, 24 hours, limed.
183, Copper sulphate, $\frac{9}{10}$% solution, 24 hours.
189, Copper nitrate, 5% solution, 24 hours.
191, Copper nitrate, 5% solution, 24 hours, limed.
247, Corrosive sublimate (mercuric chloride), $\frac{1}{10}$% solution, 24 hours.
281, Corrosive sublimate (mercuric chloride), 1% solution, 9 hours.

IX.

Having from 1 to 3% Smut (4 Treatments).

177, Copper sulphate, $7\frac{3}{5}$% solution, 24 hours, limed.
231, Verdigris, 5% solution, 24 hours.
289, Potassium bichromate, 5% solution, 24 hours.
309, Castile soap, 10% solution, 24 hours; washed after treatment.

X

The following 7 treatments destroyed all the grain.

179, Copper sulphate, $9\frac{9}{10}$% solution, 24 hours.
249, Copper nitrate, 5% solution, 2 hours; previously soaked 24 hours.
253, Potassium bichromate, 10% solution, 23 hours.
261, Ammonium hydrate vapor, 36 hours.
267, Verdigris, 5% solution, 19 hours.
275, Soda (sodium hydrogen carbonate), 1% solution, 24 hours; then immersed 2 minutes in copper sulphate, 10% solution.
285, Mixture of equal parts of copper sulphate, 10% solution and soda 5% solution, 2 hours; previously soaked 24 hours.

The most valuable treatments are without doubt comprised in lists I and II, since these treatments increased the yield and destroyed all the smut or had less than 1 per cent. of smut.

The different forms of the hot-water treatment make up the great bulk of both of these lists. The only other treatment which gave results at

all comparable with those obtained by using hot water was that with $\frac{1}{2}$ to $\frac{3}{4}$ per cent. solutions of potassium sulphide in which the seed was allowed to stand 24 hours. When fresh solutions were used a $\frac{1}{4}$ per cent. solution (plot 159) did not prevent all the smut, a $\frac{3}{4}$ per cent. solution (plot 155) destroyed all the smut but injured the stand, while a $\frac{1}{2}$ per cent. solution (plot 157) destroyed all the smut without injuring the stand. The solutions used in treating the seed for these plots were allowed to stand 6 days when they were used again for plots 201–205. The solutions had meanwhile partially decomposed so that on this second trial a $\frac{3}{4}$ per cent. solution gave about the same result that a $\frac{1}{2}$ per cent. solution did when first made.

Aside from the hot-water method, the most promising treatment we have tried is potassium sulphide. This chemical would cost about 25 cents a pound and a pound would make 24 gallons of solution.

Of the hot-water treatments seven plots (63, 67, 91, 103, 109, 129, 143) were planted with seed that was allowed to cool gradually after immersion in hot water. In every instance corresponding plots were planted with grain treated in exactly the same manner but cooled after immersion by being plunged into cold water. The cooled and uncooled seed was planted in adjacent plots separated by a single untreated plot.

In every case the plots treated with seed cooled gradually gave a less per cent. of smut than those planted with seed cooled as usual. The seven plots planted with uncooled seed averaged .27 per cent. smutted while the correspondent plots with cooled seed had on the average .87 per cent. smut. Three (67, 91, 109) of the former had no smut, while all of the latter were more or less smutted. The yield was about the same, but average $\frac{1}{4}$ bushel per acre lower for the plots planted with uncooled seed.

Such a result might very naturally be expected, since the real effect of not quickly cooling the seed is simply to prolong the action of the hot water. It is very evident that such action would persist longest in the interior of a mass of a grain, and thus might overtreat (and injure) some of the grain while other parts were not yet sufficiently treated. The use of cold water insures the treatment of each grain in nearly the same degree. It may yet be found possible and desirable to omit cooling the seed, especially if it be spread out in a uniform layer immediately upon being taken from the water.

In a number of plots (11, 27, 31, 39, 43, 45, 81, 87, 93, 99, 105, 119) the seed treated in hot water had been previously soaked several hours in cold water. The effects of this soaking were as expected: the smut was fully prevented by a shorter immersion or by treating at a lower temperature than is necessary when dry seed is used. Further experi-

ments will be necessary before this form of the hot-water treatment can be recommended. Without doubt previously soaking the seed will greatly shorten the time necessary for the treatment—perhaps to 5 minutes.

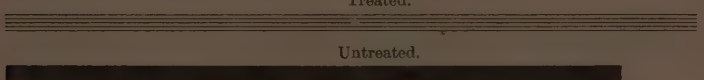
Treating the seed for a short time in water of a higher temperature was also found to be effective in destroying the smut. It is likely, however, that in treating dry seed at high temperatures that there will be danger of leaving a few seed unwetted, especially when large quantities are treated at once. There is also danger that the center of the mass of seed will not have time to become heated to the temperature of the water.

Because of the uncertainty of these modifications of the hot-water treatment, we recommend as before the immersion of dry seed 15 minutes at 132½° F.

INCREASED YIELD OF STRAW IN TREATED PLOTS.

Our experiments seem to show a small increase in the yield of straw from treated plots over that of untreated plots. This increase in the amount of straw produced is of some importance since oat straw is a valuable cattle food.

The following graphic representation shows the comparative yield of straw in treated and untreated plots. The five most valuable treatments (47, 69, 157, 39, 67) were averaged and compared with the average of the four nearest untreated plots in each case, or with the average of 20 plots in all. The barred line represents the yield of straw in the treated plots and the black line that of the untreated plots.



SPREADING OF SMUT IN FIELDS.

Plots 223, 225, 227 and 229 were planted with oats raised on J. F. Swingle's farm in 1889. The first three were planted with seed from plots I, II and III, of the experiment reported in Bull. 8, pp. 95 and 96, (Second Annual Report, pp. 246-248.) Plot 229 was planted with seed from the same field. The following statement shows the amount of smut in the two years:

Plot 223, planted with oats that had 4.67 % smut in 1889 gave 8.55 % in 1890
" 225, " " " " " 0 % " " " " 2 % " "
" 227, " " " " " 8.11 % " " " " 10.21 % " "

Plot 229 gave 10.39 per cent. of smut this year, while the field from which it was obtained was from 7 to 8 per cent. smutted in 1889. In every

case there was an increase in the amount of smut over last year. Perhaps this was due to the changed soil and different weather.

The most important fact to be noted is that plot 11, which did not produce a smutted head in 1889, yielded seed that gave a crop 2 per cent. smutted. In 1889 the plot was very favorably located for becoming infected from the surrounding smutty oat field. The plot was a narrow strip bordering directly along one side and at both ends on oats infested with smut. The results of this experiment add another link to the already strong chain of evidence that in order to keep oats free from smut they must not be grown near fields infested with smut.

PROPORTION OF HEADS PARTIALLY SMUTTED.

Since all of the experimental plots were cut before the stalks were counted, it was impossible to obtain any facts as to the proportion of hills partially smutted. The number of partly smutted heads was, however, carefully determined in counting. Of a total of 41,167 smutted heads produced in plots 1–311, 1362, or 3.3 per cent. were partially smutted. In the tabulation the partly smutted heads are included in the number of smutted heads.

COMPARATIVE EFFECTS OF FUNGICIDES ON WHEAT AND OATS.

A comparison of the results here published with those for wheat given in Bulletin 12, shows that oats are injured by chemical solutions much more easily than wheat. The effect of hot water is apparently about the same on both.

GRAPHIC REPRESENTATION OF INCREASED YIELD OF TREATED PLOTS.

The yields of the 47 best plots are shown graphically in the following table. In each case the ruled bar represents the yield of the treated plot, and the black bar the average yield of the two adjacent untreated plots. Each inch in length represents a yield of 16⅔ bushels per acre. In a column to the left is given the per cent. of smut in the plot or plots. All plots giving increased yield of more than 3½ bushels are included, no matter how much smut they contained. The plots are arranged in the order of increase in yield, the first plot having the greatest increase over the adjacent untreated plots.

GRAPHIC REPRESENTATION OF BEST YIELDS.

Treatment.	*Per ct. smut.*	*Comparative Yield.*
113. Hot water, 127.4° F., 5 min.	1.45	
112 and 114. Untreated.	10	
105. Hot water, 129.2° F., 5 min.; previously soaked 5 hours.	0	
104 and 106. Untreated.	9.47	
3. Hot water, 143.6° F., 5 min.	0	
2 and 4. Untreated.	8.67	
79. Hot water, 131° F., 3 min.	5.17	
78 and 80. Untreated.	10.52	
123. Hot water, 127.4° F., 20 min.	0	
124. Untreated.	10.04	
111. Hot water, 129.2° F., 15 min.	0	
110 and 112. Untreated.	10.79	
47. Hot water, 136.6° F., 10 min.	0	
46 and 48. Untreated.	12.16	
69. Hot water, 132.8° F., 15 min.	0	
68 and 70. Untreated.	11.06	
157. Potassium sulphide, ½% solution, 24 hours.	0	
156 and 158. Untreated.	7.54	
121. Hot water, 127.4° F., 15 min.	.07	
120. Untreated.	9.34	
39. Hot water, 134.6° F., 3 min.; previously soaked 3 hours.	0	
38 and 40. Untreated.	10.71	
151. Hot water, 120.2° F., 15 min.	.1	
150 and 152. Untreated.	7.37	

GRAPHIC REPRESENTATION OF BEST YIELDS—CONTINUED.

Treatment.	*Per ct. smut.*	*Comparative Yield.*
17. Hot water, 138.2° F., 3 min.	2.66	
16 and **18.** Untreated.	8.94	
83. Hot water, 131° F., 5 min.	2.54	
82 and **84.** Untreated.	10.92	
101. Hot water, 129.2° F., 5 min.	2.82	
100 and **102.** Untreated.	10.65	
13. Hot water, 140° F., 5 minutes.	.32	
12 and **14.** Untreated.	10.00	
217. Sodium hyposulphite, 2⅔% solution, 24 hours.	2.36	
216 and **218.** Untreated.	17.85	
67. Hot water, 132.8° F., 10 min.; not cooled.	0	
66 and **68.** Untreated.	10.53	
27. Hot water, 136.4° F., 3 min.; previously soaked 3 hours.	0	
26 and **28.** Untreated.	8.62	
201. Potassium sulphide, ¾% solution, 24 hours.	0	
200 and **202.** Untreated.	14.58	
203. Potassium sulphide, ½% solution, 24 hours.	.5	
202 and **204.** Untreated.	14.38	
37. Hot water, 134.6° F., 3 min.	2.65	
36 and **38.** Untreated.	12.34	
103. Hot water, 129.2° F., 5 min.; not cooled.	.51	
102 and **104.** Untreated.	10.2	
133. Hot water, 125.6° F., 20 min.	0	
132 and **134.** Untreated.	9.98	

GRAPHIC REPRESENTATION OF BEST YIELDS – CONTINUED.

Treatment.	*Per ct. smut.*	*Comparative Yield.*
19. Hot water, 138.2° F., 5 min.	.48	
18 and 20. Untreated.	9.	
119. Hot water, 127.4° F., 10 min.; previously soaked 5 hours.	0	
118 and 120. Untreated.	9.54	
137. Hot water, 128.8° F., 10 min.	.03	
136 and 138. Untreated.	8.5	
131. Hot water, 125.6° F., 15 min.	.1	
130 and 132. Untreated.	9.73	
93. Hot water, 131° F., 10 min.; previously soaked 8 hours.	0	
92 and 94. Untreated.	11.9	
75. Hot water, 131.9° F., 10 min.	.31	
74 and 76. Untreated.	8.89	
187. Copper sulphate, $\frac{1}{10}$% solution, 24 hours.	1.61	
186 and 188. Untreated.	13.65	
109. Hot water, 129.2° F., 10 min.; not cooled.	0	
108 and 110. Untreated.	11.13	
205. Potassium sulphide, ½% solution, 24 hours.	.21	
204 and 206. Untreated.	16.53	
89. Hot water, 131° F., 10 min.	.55	
88 and 90. Untreated.	11.39	
59. Hot water, 132.8° F., 3 min.	3.34	
58 and 60. Untreated.	10.48	
127. Hot water, 125.6° F., 10 min.	.8	
126 and 128. Untreated.	9.09	

GRAPHIC REPRESENTATION OF BEST YIELDS—CONCLUDED.

Treatment.	*Per ct. smut.*	*Comparative Yield.*
115. Hot water, 127.4° F., 5 min.; previously soaked 5 hours.	0	
114 and **116.** Untreated.	10.09	
15. Hot water, 140° F., 10 min.	0	
14 and **16.** Untreated.	9.22	
141. Hot water, 122° F., 10 min.	1.12	
142. Untreated.	9.67	
57. Hot water, 133.7° F., 15 min.	0	
56 and **58.** Untreated.	11.06	
81. Hot water, 131° F., 3 min.; previously soaked 8 hours.	.14	
80 and **82.** Untreated.	10.95	
11. Hot water, 140° F., 3 min.; previously soaked 8 hours.	.07	
10 and **12.** Untreated.	10.48	
35. Hot water, 136.4° F., 10 min.	0	
34 and **36.** Untreated.	12.78	
159. Potassium sulphide, ¼% solution, 24 hours.	.12	
158 and **160.** Untreated.	6.98	
207. Soda, 10% solution, 24 hours.	4.32	
208. Untreated.	12.38	
143. Hot water, 122° F., 10 min.; not cooled.	.76	
142 and **144.** Untreated.	8.73	
129. Hot water, 125.6° F., 10 min.; not cooled.	.18	
128 and **130.** Untreated.	9.41	

REMARKS ON THE FOREGOING GRAPHIC TABLE.

No great importance should be attached to the sequence of plots in the foregoing table. It is not unlikely that the results of another season's experiments would change it materially since untreated plots, under apparently the same conditions, varied greatly in yield. No doubt some similar variation occurred among the treated plots, aside from that due to differences in treatment of the seed. In many instances the very great increase shown in the table is due to the fact that one or both of the untreated plots, used in comparison, had a yield below the average.

INCREASE IN YIELD OF TREATED PLOTS ABOVE THE AMOUNT THAT WOULD BE OBTAINED BY REPLACING SMUTTED HEADS WITH SOUND ONES.

By studying the graphic representations given above or by examining the tabulation of experiments on pp. 105 113, it may be seen that very many of the plots gave a yield greatly exceeding that which would result from simply replacing the smutted heads in the untreated plots with sound ones. In fact almost all of the plots shown above gave such an extra increased yield. Several of the plots had some smut and yet a greatly increased yield; yet since a treatment to be of practical value must destroy *all* the smut, they are disregarded in the following.

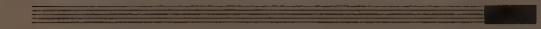
Taking the first ten plots of the above graphic representation that had no smut, (105, 3, 123, 111, 117, 47, 69, 157, 39, 67, 27,) and yet a full or nearly a full stand, and comparing them with the averages of each two adjacent plots, gives a result that may be stated as follows:

The direct damage in the untreated plots, resulting from part of the heads being smutted, averaged 11.34 per cent. The treated plots gave an average yield 45.27 per cent. greater than that of the untreated plots, or *nearly 4 times as great an increase as would be obtained by merely replacing the smutted heads in the untreated plots with sound ones.*

This remarkable increase is shown graphically in the following bar. The ruled portion represents the average yield of the 20 untreated plots adjoining the 10 treated plots. The total length represents the average yield of the treated plots. The black part represents the increase that would be obtained by replacing smutted heads with sound in the untreated plots. The white portion thereof represents the increase in the yield above the amount directly destroyed by smut. It is made on a scale of an inch to $16\frac{3}{8}$ bushels per acre.

Since some of the very largely increased yields were due to the fact that one or both of the untreated plots adjoining having an unusually low yield, probably the foregoing bar exaggerates the increase that could

be obtained in actual practice. To avoid this source of error the five plots were selected which will probably prove best in general practice. These five (47, 69, 157, 39, 67) were each compared with the average of the *four* nearest untreated plots. Each plot was therefore compared with the average of the two untreated plots immediately adjoining it on either side, and also with the two separated from it by a single treated plot. By taking the *four* nearest untreated plots for comparison the effect of any accidental low yield was neutralized. The average direct damage from smut in the untreated plots was 11.4 per cent., while the average increase of the treated plots was 34.49 per cent., *or more than 3 times the amount of direct damage from smut in untreated.* This result is shown graphically in the following bar, which is made in the same manner as the previous one.



In this case there can be no doubt that the great increase did occur, and it is highly probably that a like increase would be realized in practice if the oats were infested with smut to the same extent as those grown in the above experiments.

OTHER EXPERIMENTS SHOWING SIMILAR INCREASED YIELDS.

All other accurate experiments with oats have shown a similar increase in the yield from disinfecting the seed, much greater than would occur from simply eliminating the direct damage from smut.

In October, 1889, in Bulletin 8, p. 96, we reported an experiment made that year showing such a greatly increased yield that we said: "It is impossible to account for the great superiority of plot II over the others, unless besides killing the smut the Jensen treatment also caused the seed to germinate better." This portion of Bulletin 8 is reprinted in the Second Annual Report, p. 248.

In his experiments with the hot-water method, carried on in the same year, Mr. J. L. Jensen found an increased yield above the amount directly destroyed by smut. His experiments are quoted in our Second Annual Report, p. 248. In the two trials made at different places in Denmark the untreated seed in both instances gave less than $\frac{1}{4}$ per cent. smutted heads, yet an increase of nearly 5 per cent. was in both cases obtained by treating the seed.

CAUSE OF THE EXTRA INCREASE IN YIELD.

As may be seen from the quotation given above, in our previous reports we accounted for the increased yield above the amount of direct damage from smut by assuming that the Jensen treatment caused the seed to germinate better. Jensen, in a letter dated January 24, 1890, gives a

similar view, saying* "I suppose this remarkable fact must be due to a greater vegetative energy in the treated seed." This explanation may account for a part of the increase in yield, but seems entirely inadequate to account for the extra increase observed in our experiments, both in 1889 and 1890.

In April, 1890, Jensen published a pamphlet,† in which he suggests that very many plants are attacked by smut which never reaches the head but simply weakens the plant. Of course the hot-water treatment prevents this "invisible" smut as well as that which destroys the heads. At present there is little evidence of the existence of any invisible smut, but if proven to occur the destruction of it would explain in part at least the extra augmentation of the yield when seed is treated.

AMOUNT OF DAMAGE FROM SMUT.

It has been assumed that the loss from smut is merely equal to the amount of increased yield in case the smutted heads were replaced by sound ones, yet experiments by Jensen, the originator of the hot-water method of treatment, as well as our own trials, seem to establish the fact that an extra augmentation results from the employment of this method. The yield has been increased at least twice as much as would be expected from the mere replacement of smutted heads by sound ones. On this basis therefore the 6.5 per cent. of smutted heads found in the 20 counts made the present year, would represent a damage from smut of at least 13 per cent.

The yield of oats in Kansas for 1890 is estimated by Secretary M. Mohler, (Report of Kansas State Board of Agriculture for the month ending Sept. 30, 1890,) at 29,175,582 bushels. If smut caused a damage of 13 per cent., this amount would represent only 87 hundredths of what the crop would have been had the seed been treated. The true loss would therefore be 4,359,569.7 bushels. This would make a loss to the State (if we take the price as 40 cents per bushel) of $1,743,827.88. Correcting also the estimates for the two previous years, in the same manner, (but taking the price per bushel at the prevailing rate in these years,) we have as follows:

Loss for 1888	$2,764,656 62
Loss for 1889	1,701,069 52
Loss for 1890	1,743,827 88
Total loss for three years	$6,209,554 02

The loss, therefore, in this State alone for three years, reaches the enormous sum of over six million dollars!

*The portion of his letter containing the sentence quoted was printed in *The Industrialist*, Vol. XV, No. 25, February 22, 1890, p. 97.

†J. L. Jensen, Udbytteformerelsen ved Varmvandsmethoden, April, 1890.

It should be remembered that no cash outlay would, on an ordinary farm, be required to prevent the ravages of smut. The labor and the fuel necessary for treating the seed with hot water would be quite inconsiderable. Moreover, the labor and expense of all the operations of raising and harvesting a smutty crop are the same as required for a sound crop. Neither can it be said that smut is an advantage, in that it, by destroying the heads, thins out or makes room for sound heads, since smut hills with all their stalks present, require as much space and take at least as much nourishment from the soil as sound ones.

DIRECTIONS FOR TREATING THE SEED.

The Jensen Hot-Water Treatment.

The hot-water treatment consists in immersing the seed which is supposed to be infected with smut, for a few minutes in scalding water. The temperature must be such as to kill the smut spores, and the immersion must not be prolonged so that the heat would injure the germ or embryo concealed within the seed-coats. If the water is at a temperature of 132½° F., the spores will be killed, and yet the immersion, if not continued beyond fifteen minutes, will not in the least injure the seed. The smut spores will possibly be killed by ten minutes' immersion. A fifteen-minute immersion, however, is recommended. The temperature must be allowed to vary but little from 132½°, in no case rising higher than 135°, nor falling below 130°. To insure these conditions when treating large quantities of seed, the following suggestions are offered:

Provide two large vessels, as two kettles over a fire, or boilers on a cook-stove; the first containing warm water (say 110°–130°), the second containing scalding water (132½°).

The first is for the purpose of warming the seed preparatory to dipping it into the second. Unless this precaution is taken, it will be difficult to keep the water in the second vessel at a proper temperature.

The seed which is to be treated must be placed, a half bushel or more at a time, in a closed vessel that will allow free entrance and exit of water on all sides. For this purpose a bushel basket made of heavy wire could be used, within which spread wire netting, say 12 meshes to the inch; or an iron frame could be made at a trifling cost, over which the wire netting could be stretched. This would allow the water to pass freely, and yet prevent the passage of the seed. A sack made of loosely-woven material (as gunny-sack) could perhaps be used instead of the wire basket. A perforated tin vessel might be preferable to any of the above.*

Now dip the basket of seed in the first vessel; after a moment lift it; and when the water has for the most part escaped, plunge it into the wa-

*Mr. H. M. Cottrel, of the Farm Department, had such a vessel made, which he uses in treating oats.

ter again, repeating the operation several times. The object of the lifting and plunging, to which might be added also a rotary motion, is to bring every grain in contact with the hot water. Less than a minute is required for this preparatory treatment, after which plunge the basket of seed into the second vessel. If the thermometer indicates that the temperature of the water is falling, pour in hot water until it is elevated to 132½°. If it should rise higher than 132°, add small quantities of cold water. This will doubtless be the most effectual method of keeping the proper temperature,* and requires only the addition of two small vessels—one for cold and the other for boiling water. The basket of seed should, very shortly after its immersion, be lifted, and then plunged and agitated in the manner described above; and the operation should be repeated eight to ten times during the immersion (which should be continued fifteen minutes). In this way every portion of the seed will be subjected to the action of the scalding water. Immediately after its removal dash cold water over it, or plunge it into a vessel of cold water, and then spread out to dry. Another portion can be treated similarly, and so on till all the seed has been disinfected. Before thoroughly dry, the seed can be sown.

The important precautions to be taken are as follows: 1st. *Maintain the proper temperature* of the water (132½° Fahr.), in no case allowing it to rise higher than 135° or to fall below 130°. This will not be difficult to do if a reliable thermometer is used and hot or cold water be dipped into the vessel as the falling or rising temperature demands. Immersion fifteen minutes will not then injure the seed. 2d. See that the volume of scalding water is much greater (at least six or eight times) than that of the seed treated at any one time. 3d. Never fill the basket or sack containing the seed entirely full, but always leave room for the grain to move about freely. 4th. Leave the seed in the second vessel of water *fifteen minutes.*

The Potassium Sulphide Treatment.

Our experiments this year seem to show that a weak solution of potassium sulphide is nearly if not quite as good as hot water for treating oats to prevent smut. Since this treatment may prove more convenient for treating small quantities of grain than the Jensen method, we give directions for carrying it out. The potassium sulphide is cheapest in the "fused" condition; it costs about 25 cents a pound. One pound of the sulphide should be dissolved in 24 gallons of water. Place the seed in a wooden vessel and pour on the solution till the seed is covered several inches deep. Stir the solution before pouring it on the grain and thor-

*Steam, conducted into the second vessel by a pipe provided with a stop-cock, answers very well both for heating the water and elevating the temperature from time to time.

oughly mix the seed several times before taking it out of the solution. The oats should stand in the solution 24 hours, after which they may be spread out to dry.

It will probably be best to sow the seed as soon as possible and before it becomes thoroughly dry.

SUMMARY OF IMPORTANT POINTS.

1. Oat smut is a disease caused by the attack of a parasitic fungus, called *Ustilago Avenæ.*

2. The disease is spread by the spores which become enclosed in the hulls of the grain, or perhaps rarely by spores in the soil.

3. In case of a few varieties there was found "hidden" smut that is, smut which was concealed by the normal outer glumes or chaff, yet each grain was completely destroyed.

4. The amount of smut in 1890, as based on several careful counts, was between 6 and 7 per cent. The consequent loss estimated for the entire State is $1,743,827.88.

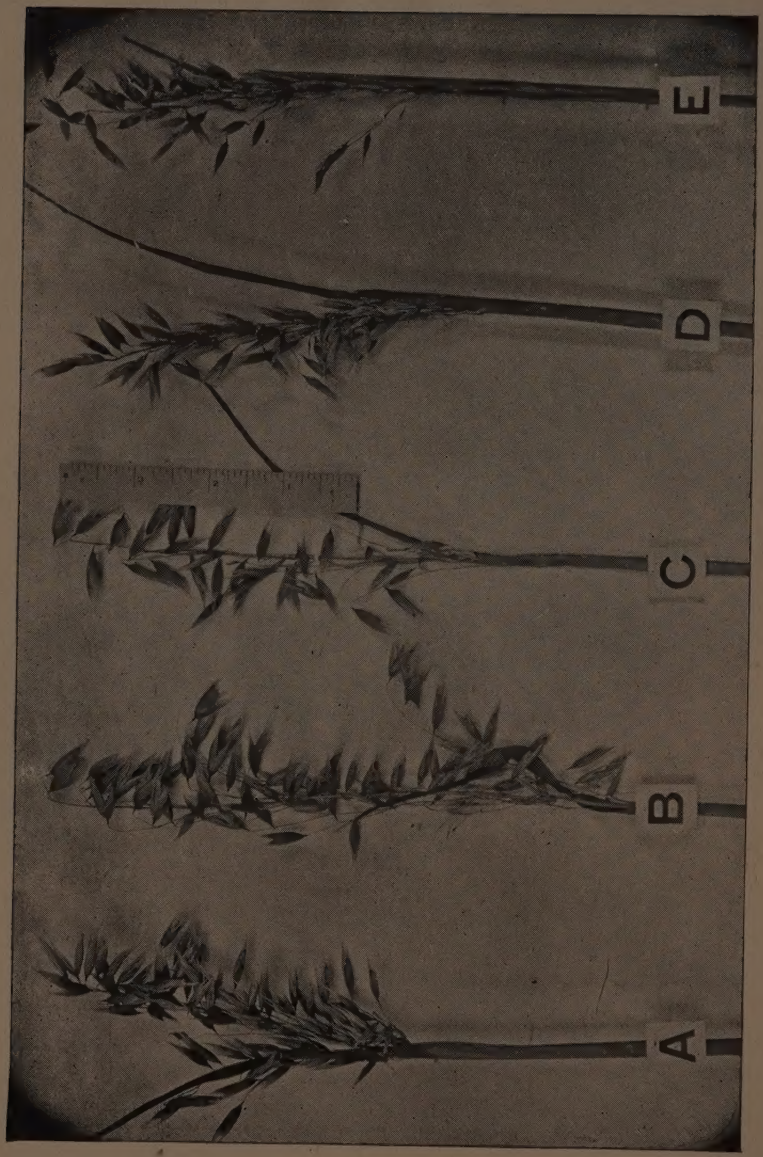
5. The extent of damage to the crop is not limited to the amount of visible smut, since treated seed gives an increase in yield at least twice as great as would result from merely replacing the smutted heads by sound ones.

6. In all ordinary cases the disease can be entirely prevented by treating the seed 15 minutes in water raised to a temperature of 132½° F.

7. The smut may also be prevented by immersing the seed 24 hours in a ½% solution of potassium sulphide. This statement however is based on a very few experiments of this year only.

8. The other fungicides tested, when destroying all or nearly all the smut, greatly injure the stand.

9. Seed from clean fields will produce a crop free from smut, but if the adjoining fields are smutty the oats will gradually become infected.



SMUT OF OATS—HIDDEN FORM.

EXPLANATION OF PLATE II.

All of the heads here represented grew in one hill of New Swedish oats, from plot 38 of the Single-Plant Variety Test (see p. 96). The plate was photo-engraved from a photograph, and represents the heads at about ¾ natural size, as may be seen from the scale of inches on the plate.

Fig. A. A head sound above but smutted below.
Fig. B. An entirely sound head.
Fig. C. An entirely sound head.
Fig. D. A head entirely smutted.
Fig. E. A head entirely smutted.

Figures D and E are too dark in the plate. The difference in color of sound and smutted heads is much less than is there shown. Figure A represents better the striking resemblance of smutted spikelets to sound ones.